How long can neutrons live?

The Center for Neutrino Physics

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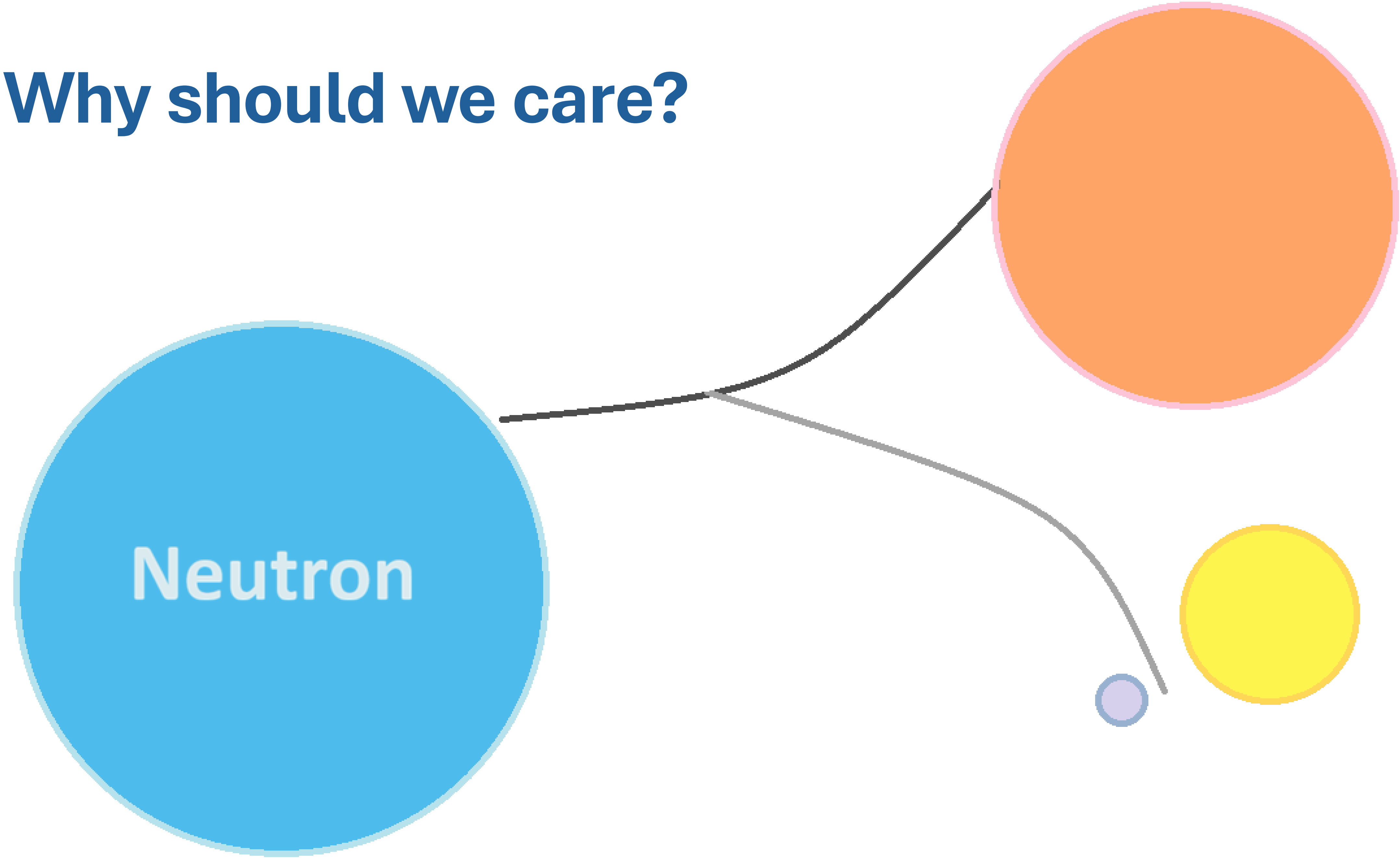
Pheno-2026

Why should we care?



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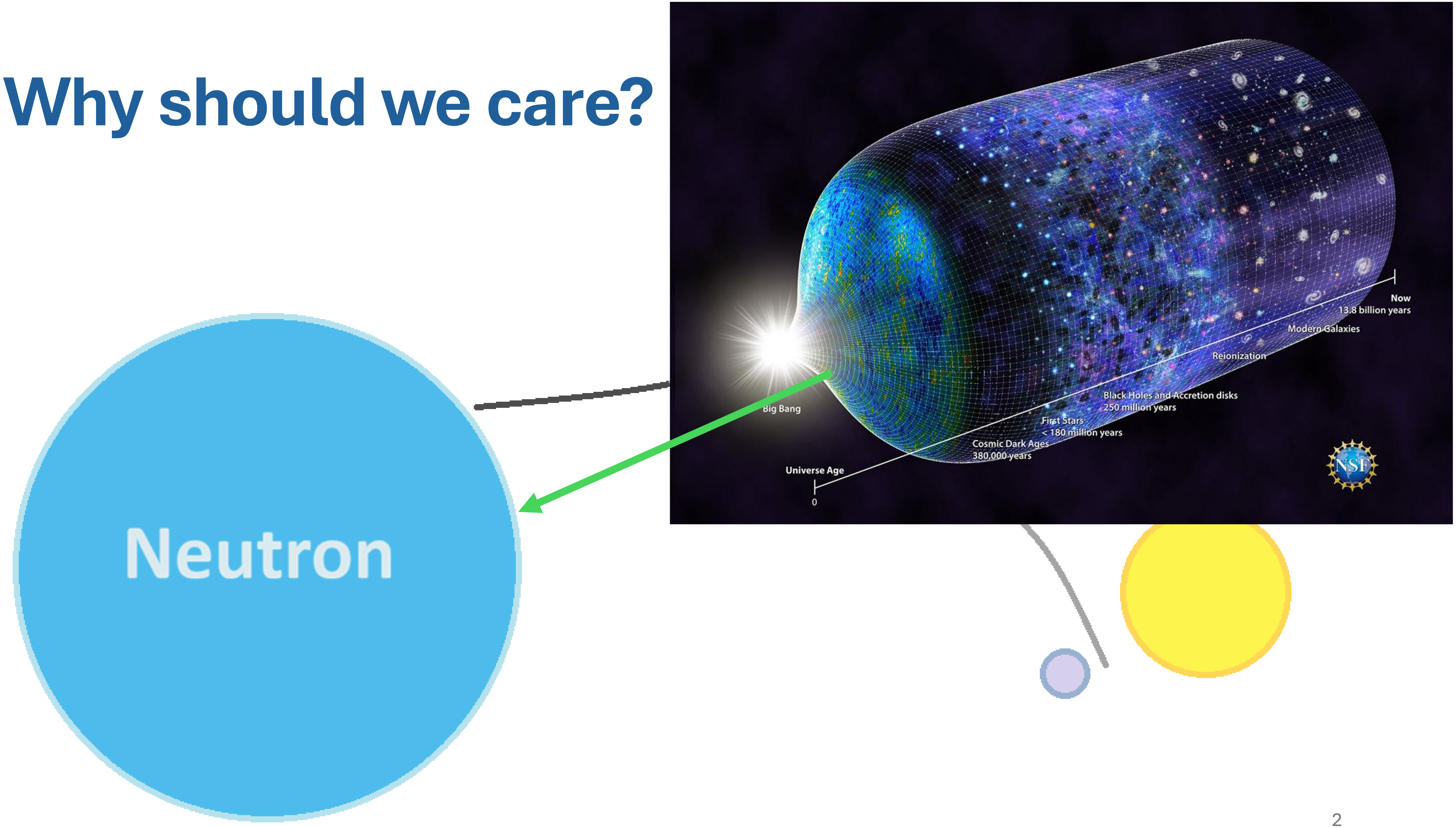

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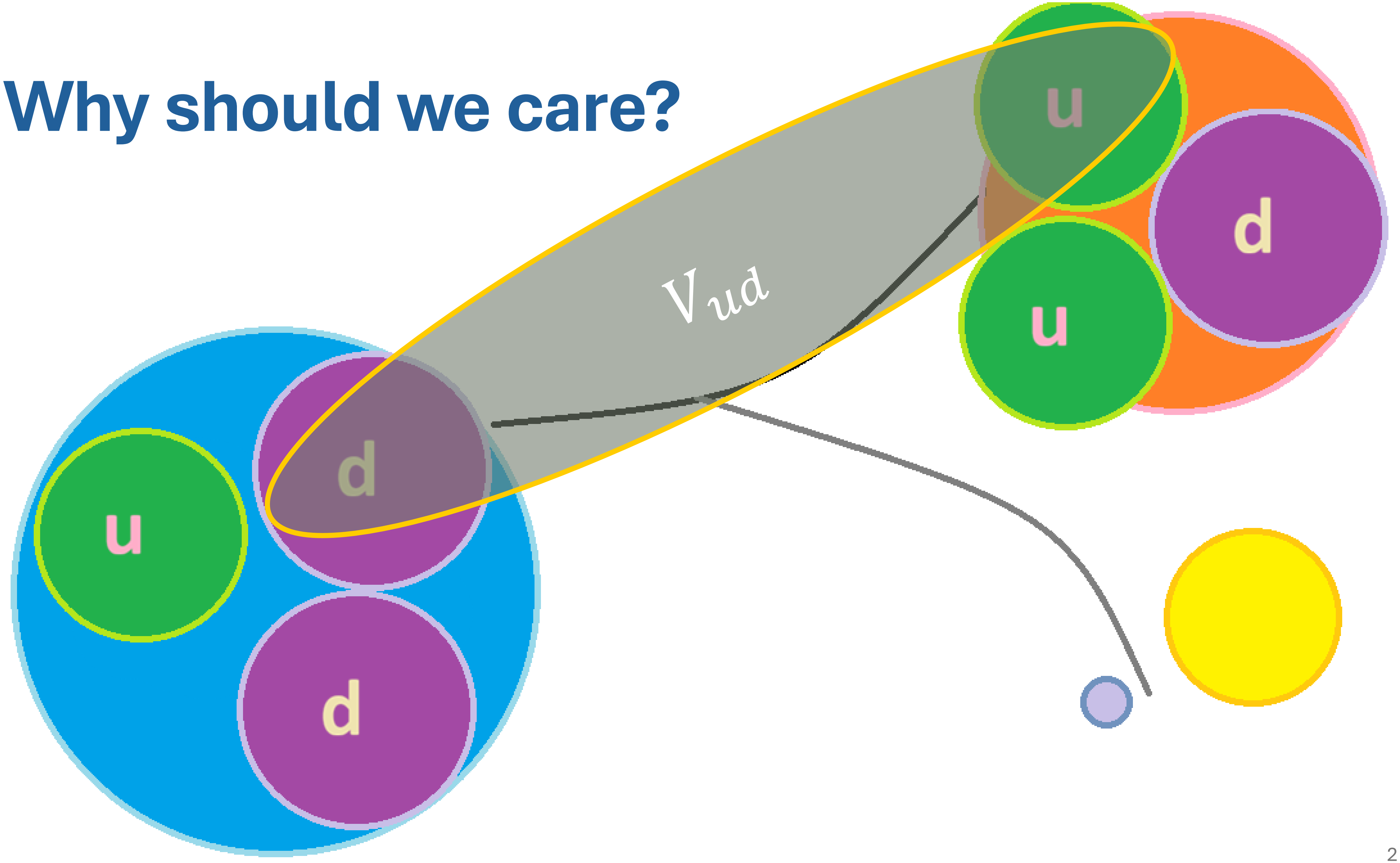
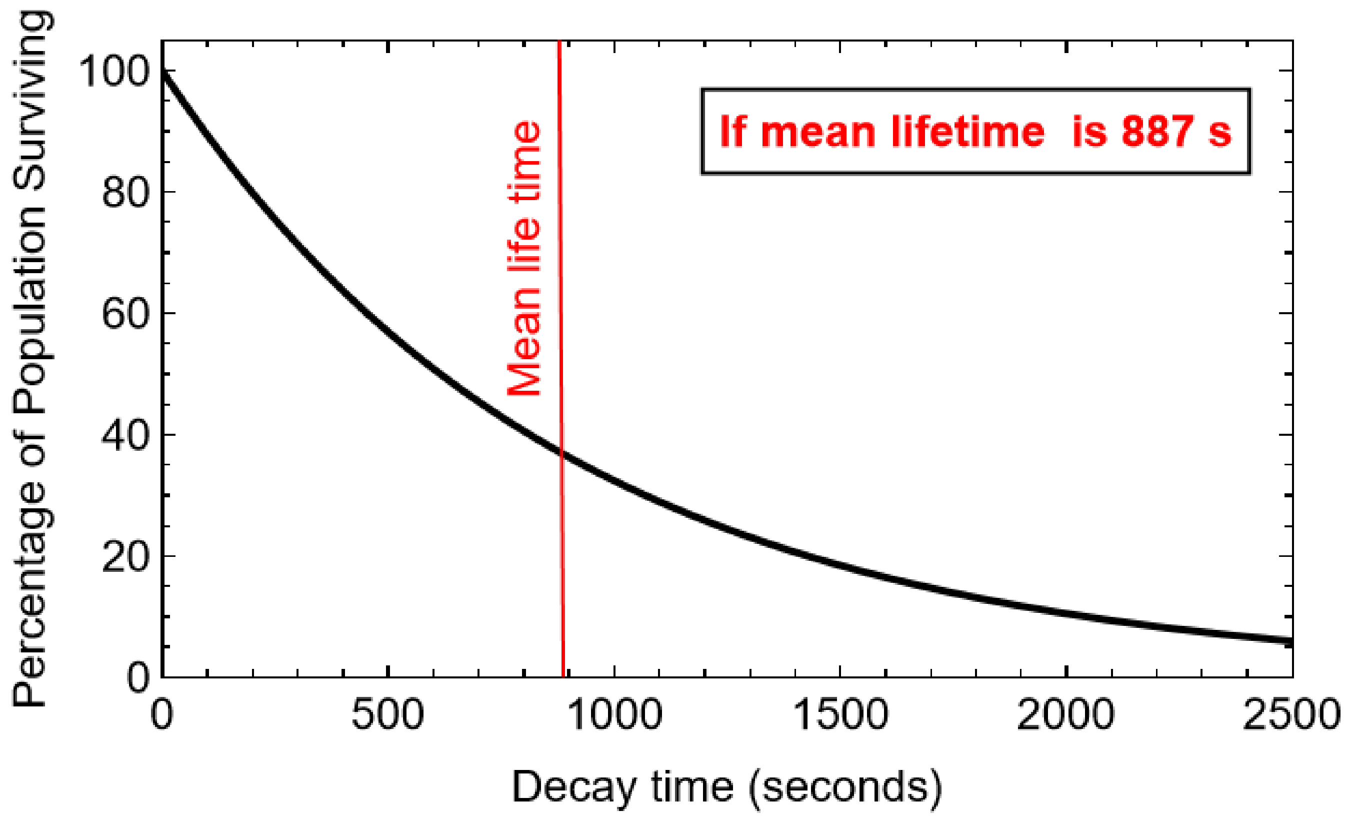
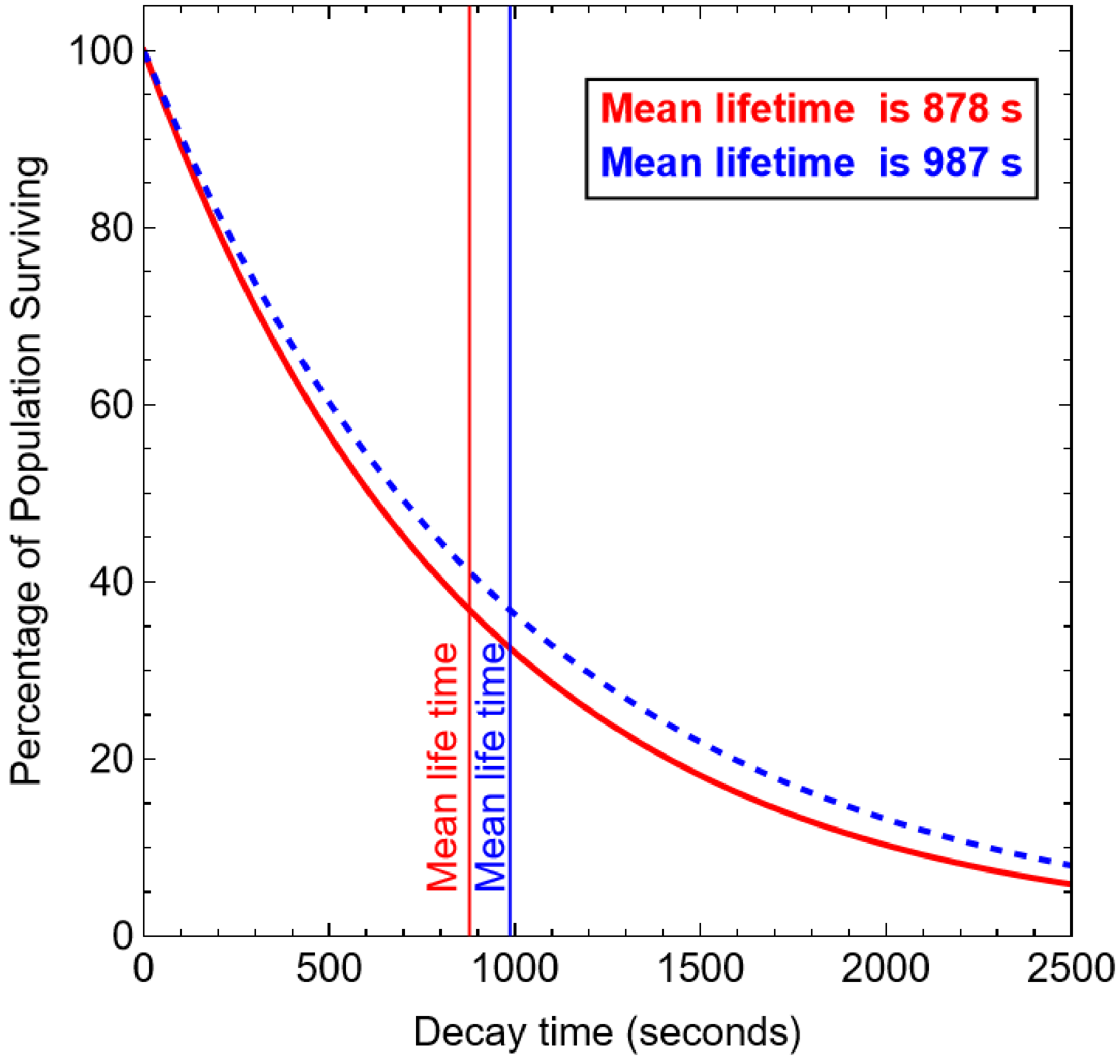


What is mean lifetime?

- For a particle decay: $N = N_0 e^{-(t/\tau)}$, τ is the mean lifetime.
- At $t = \tau$, $N = N_0/e \approx 0.367879 N_0$.



Measuring the survival rate at time t determines the mean lifetime



Two current methods of measuring n lifetime

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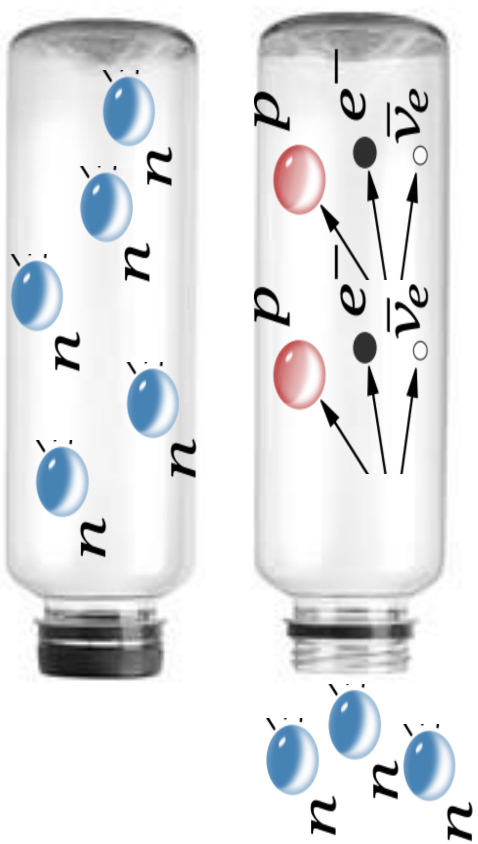
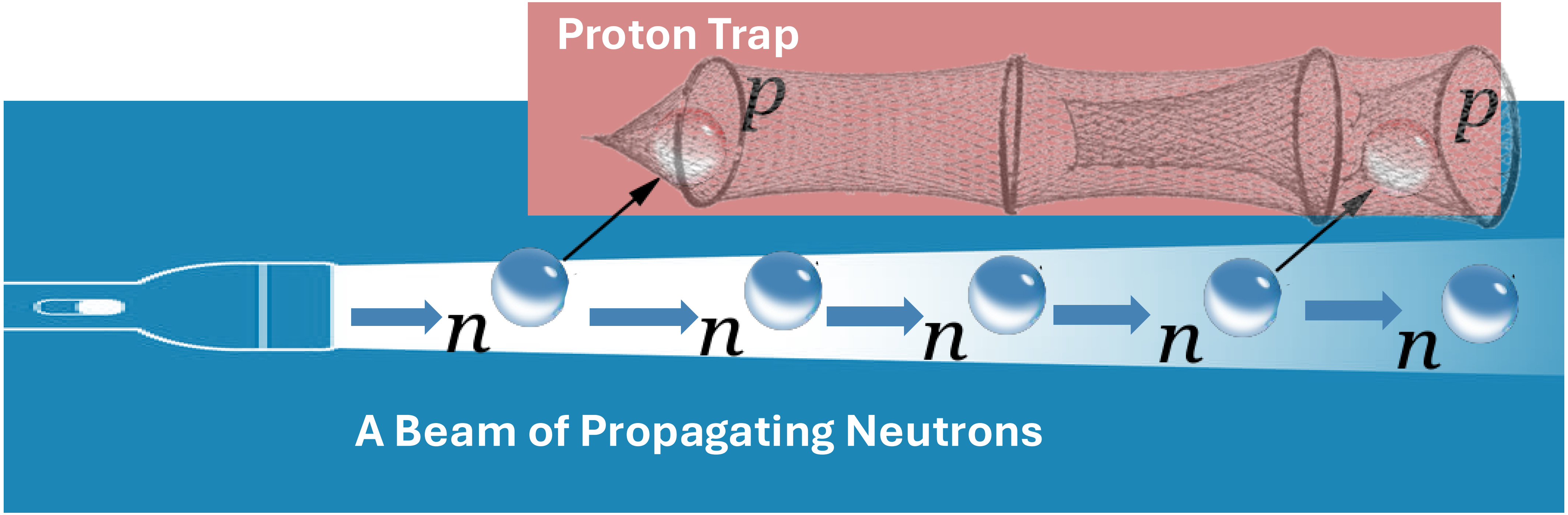
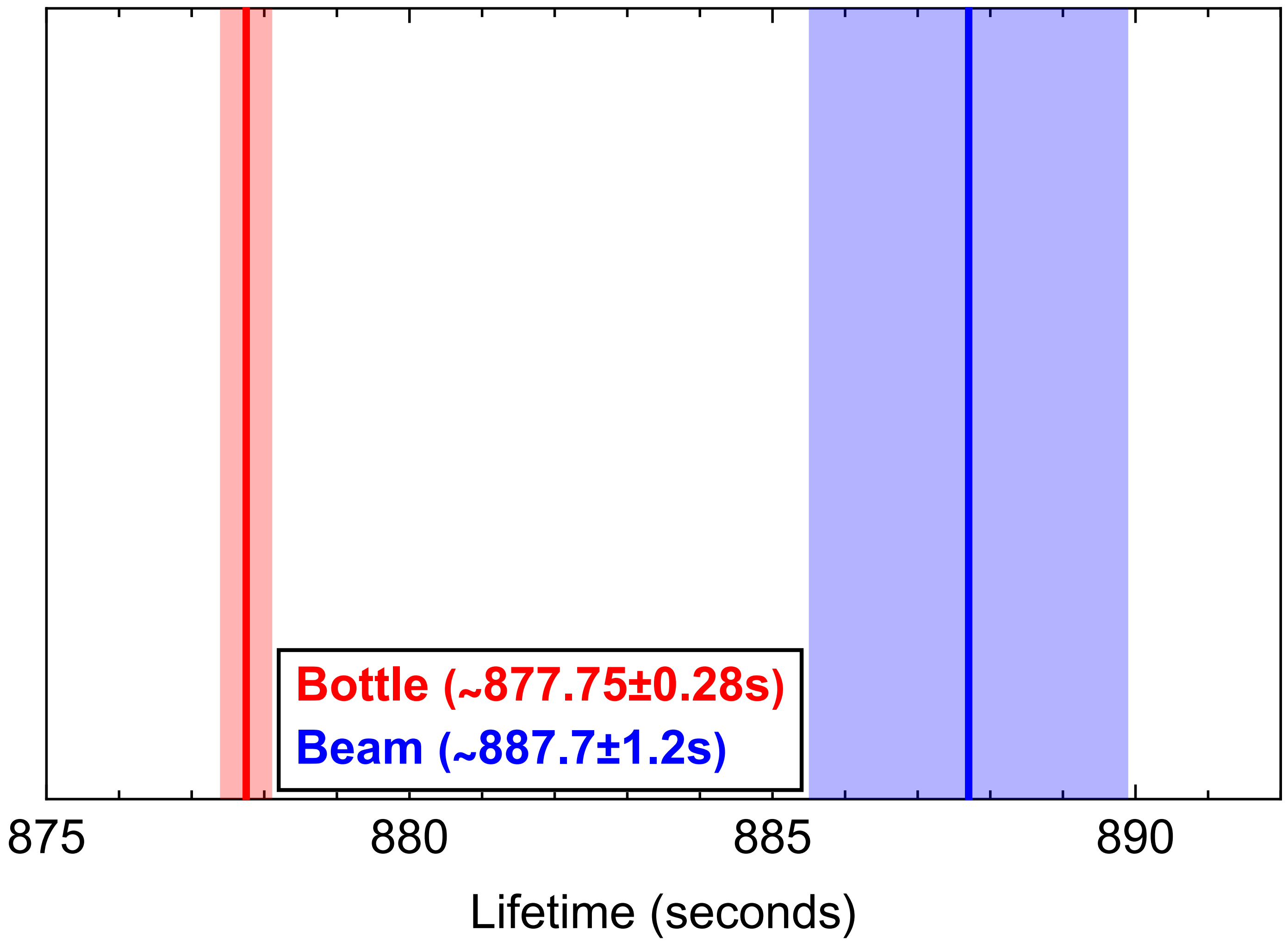


Two current methods of measuring n lifetime

2. Count the number of product particles from the neutron decay.

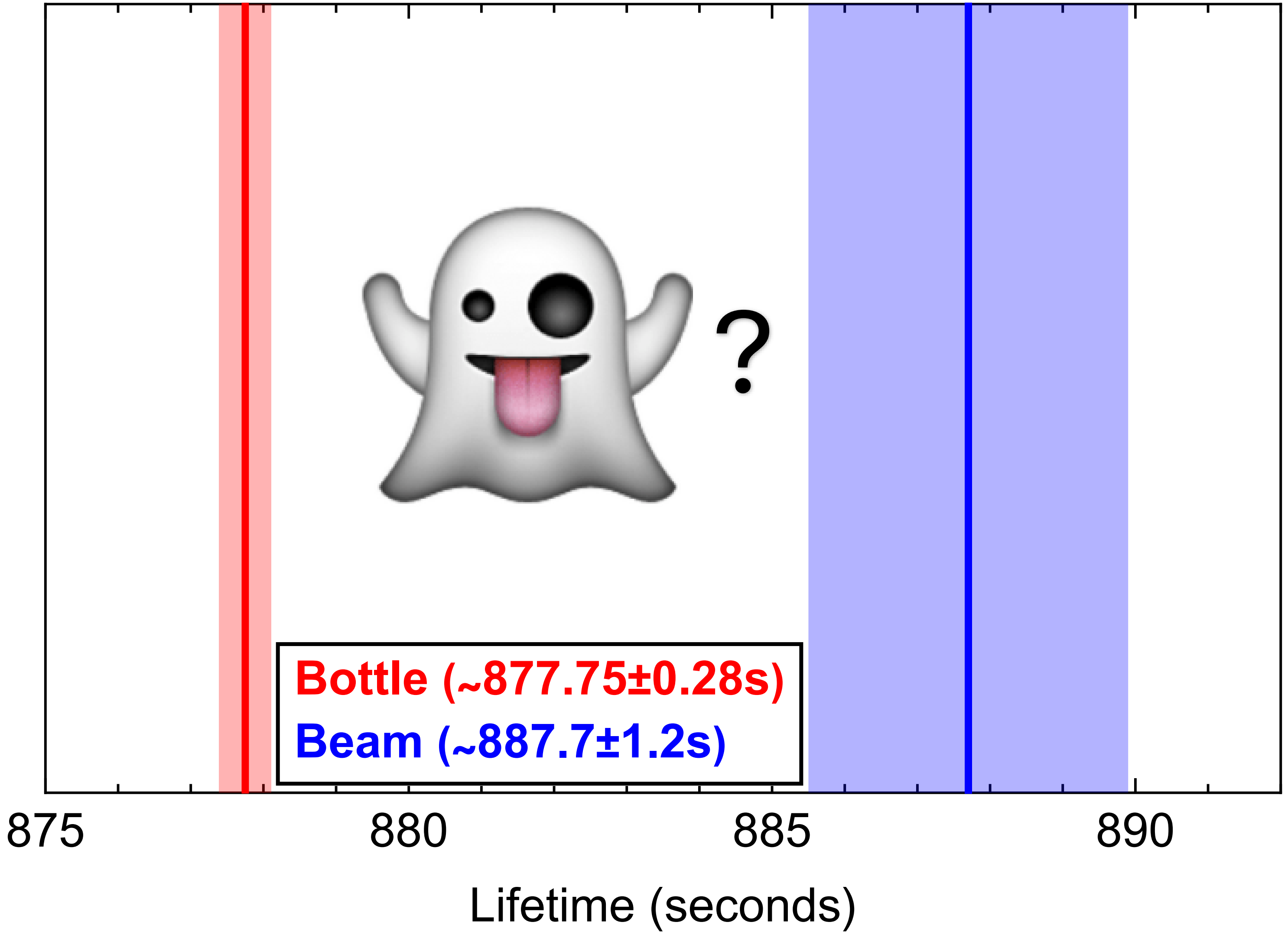


Both methods have measured lifetime accurately



1. UCNτ Collaboration (Phys.Rev.Lett. 127 (2021) 16, 162501)
2. A.T. Yue et al. (Phys.Rev.Lett. 111 (2013) 22, 222501)

What's in the gap?



We need an independent measurement

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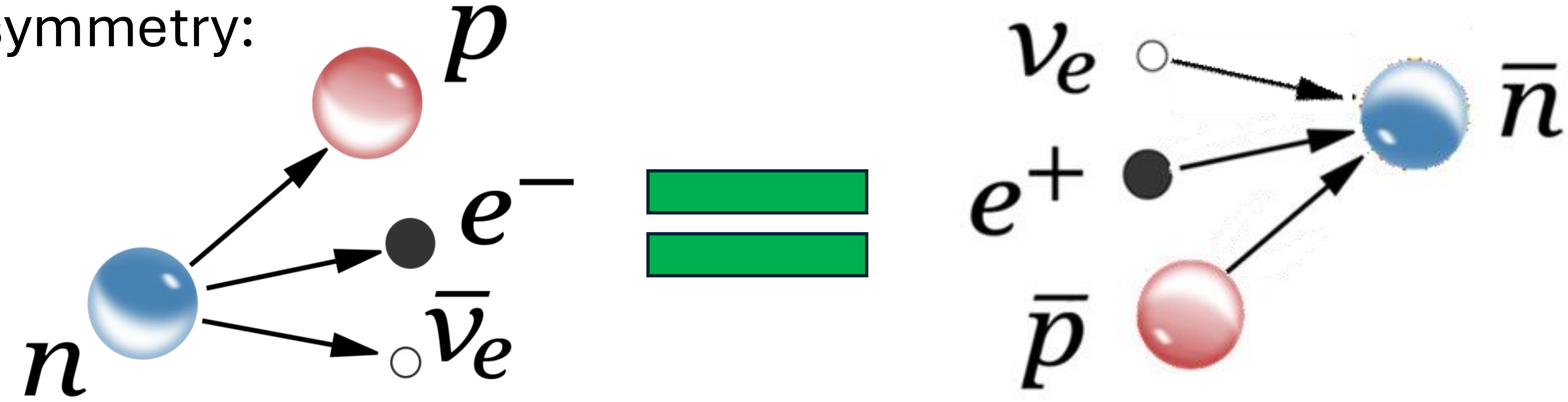
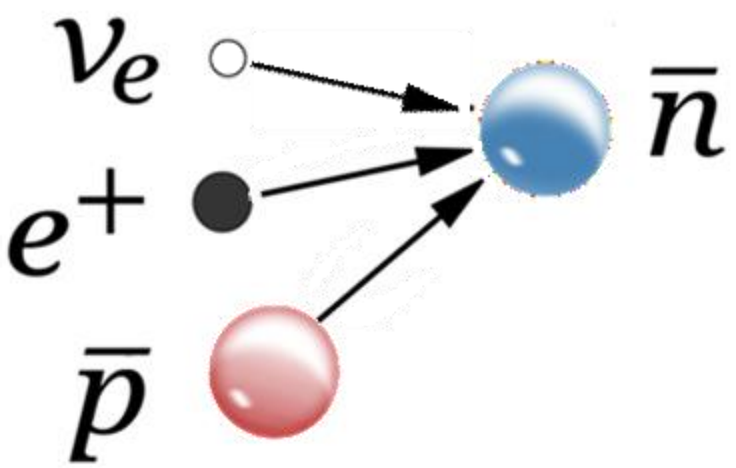
- CPT symmetry:



We need an independent measurement



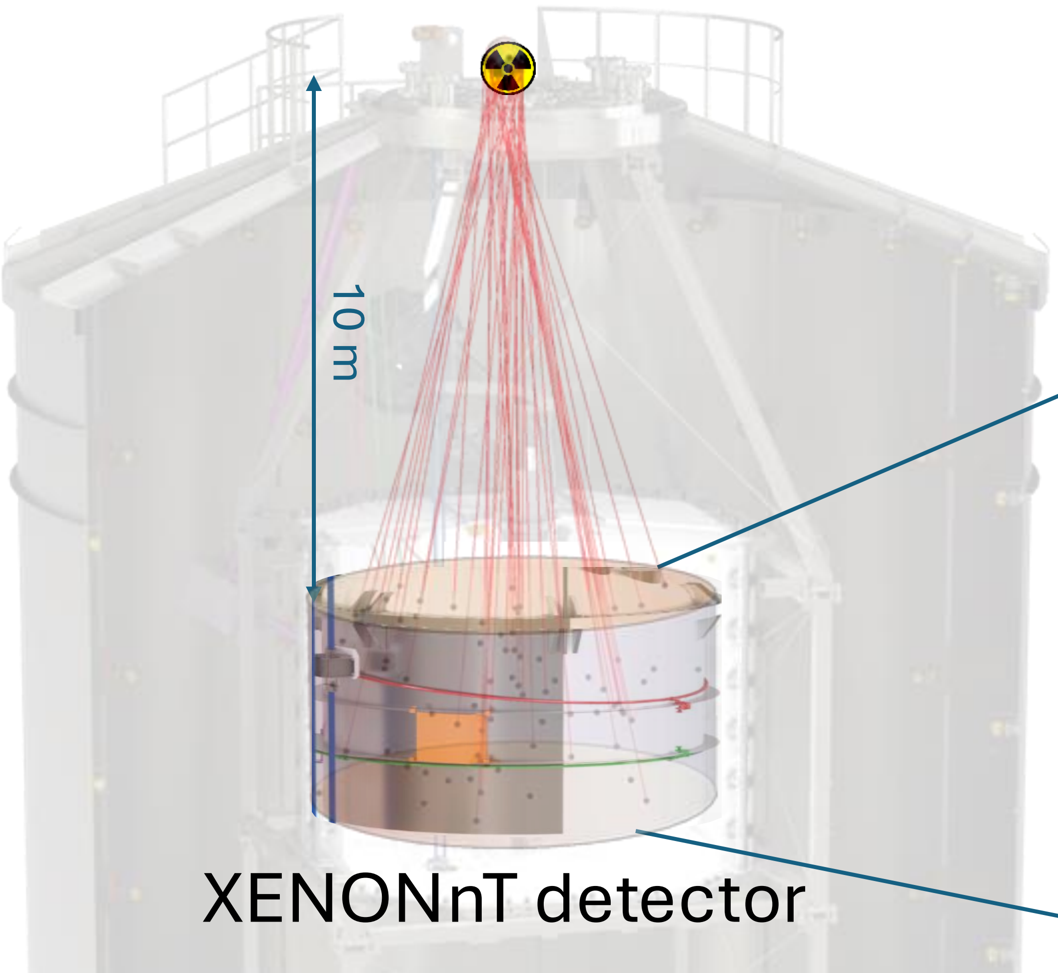
- Then, $\bar{p} + e^+ + \nu_e \to \bar{n}$ ⟹ $\bar{\nu}_e + p \to n + e^+$.

We need an independent measurement

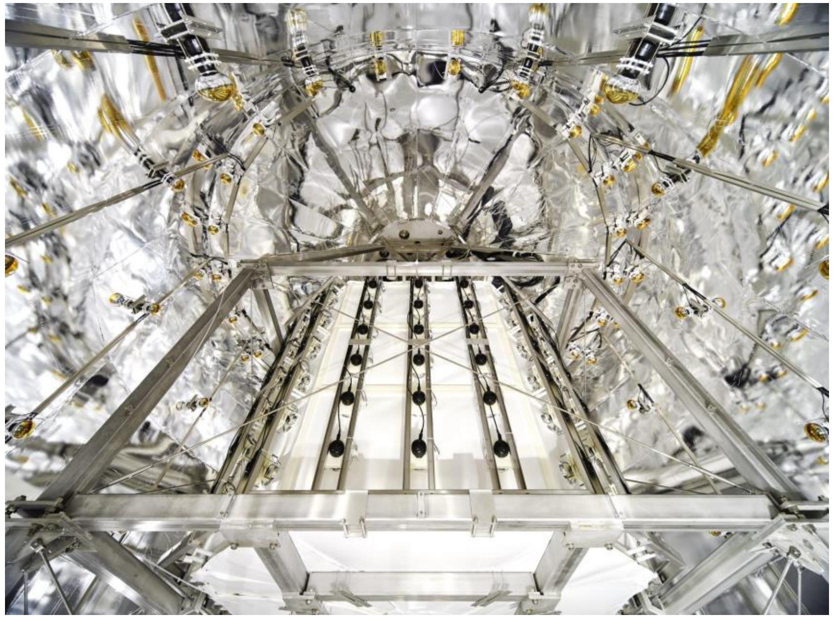
Analytically, $\sigma_{\mathrm{IBD}}^{(0)} = \frac{2\pi^2}{m_e^5 f_R \tau_n} E_e^{(0)} p_e^{(0)}$, and

$$\sigma = \sigma^{(0)}(1+\delta_{rad})(1+\Delta_{rad})(1+\delta_{rec+WM})(1+\delta_{thr})$$ [3]

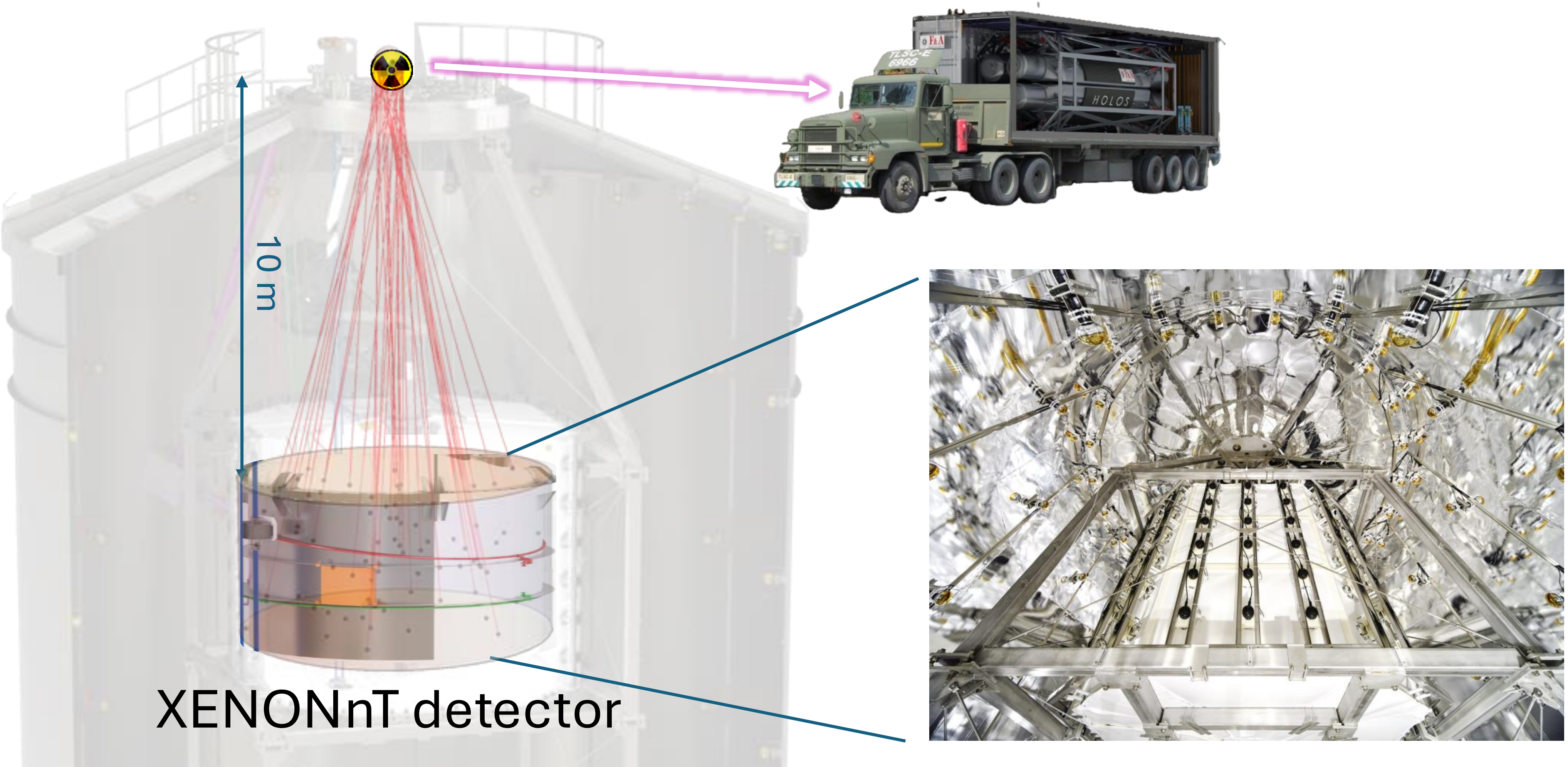
Reducing the uncertainty of the reactor ν flux



XENONnT detector



Reducing the uncertainty of the reactor ν flux



Uncertainty of neutrino flux (10 ton-year)

- CEνNS events are below the threshold cut for reactor neutrinos.
- Expect $\sim 10^5$ elastic neutrino-electron scattering (ES) events.
- We consider energy range (1-8000) keV with background. [4]
- The uncertainty of the neutrino flux normalization reduces to 0.54%.

4. XENON Collaboration, Phys.Rev.Lett. 129 (2022) 16

Uncertainty of n mean lifetime (1 ton-year)

- With more accurate reactor neutrino flux, we could measure σ_{IBD}.
- $\sigma_{IBD} = \left(9.52 \times 10^{-44} \mathrm{cm}^2\right)\left(\frac{p_e E_e}{\mathrm{MeV}^2}\right)$
- Using organic liquid scintillator, we reduce the neutron mean lifetime uncertainty to 6.3 seconds.

Outlook

- The veto cut for Electronic Recoil (ER) search is 4.37 tones, which corresponds to ~69 cm radius.
- The position resolution for simulated events is 0.75 cm within the fiducial volume (FV)[5],
- The spatial resolution could be improved to enhance the uncertainties.

5. XENON Collaboration Phys.Rev.Lett. 131 (2023) 4, 041003

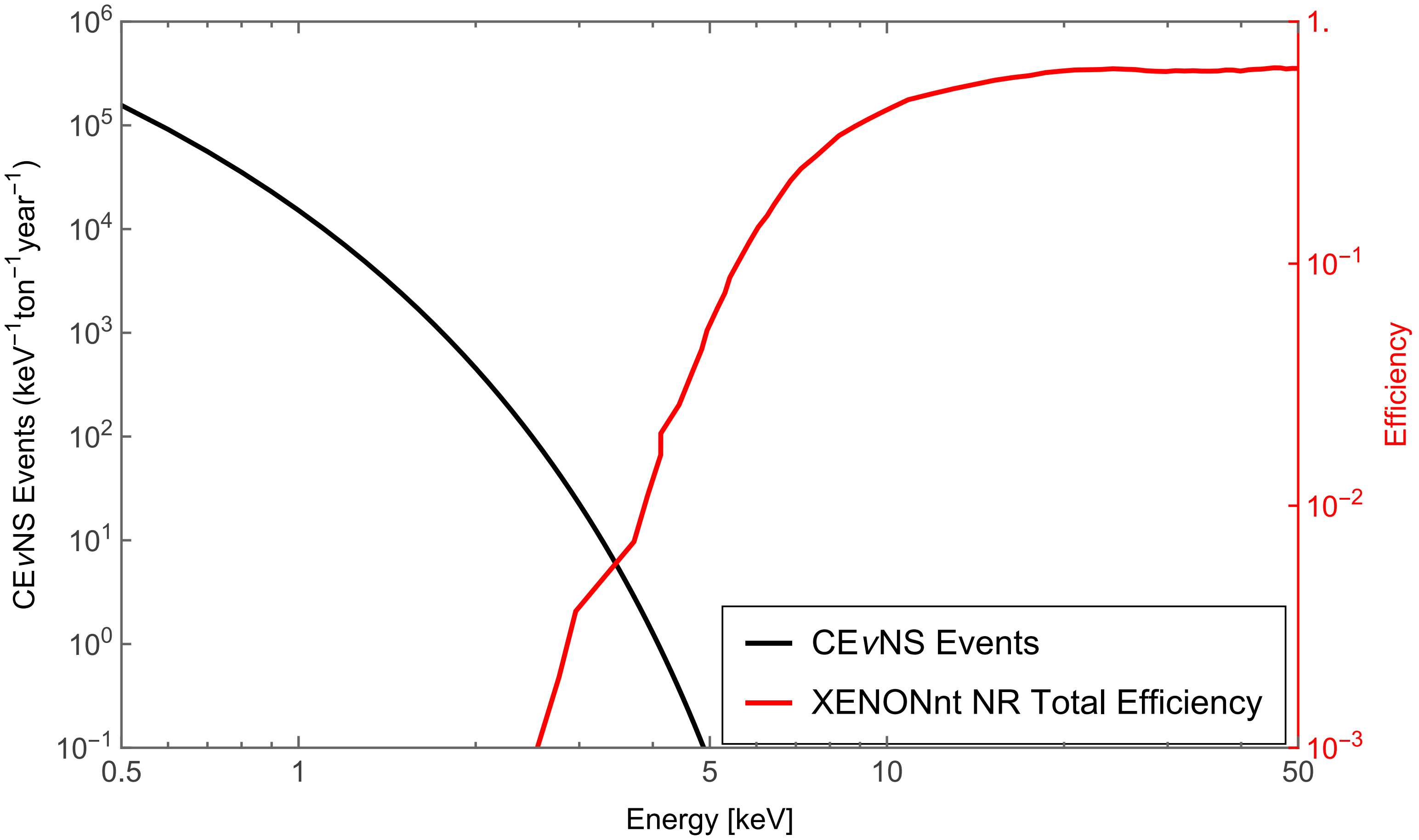
Take-away

- Using our novel setup, we could offer an independent measurement of the neutron mean lifetime that is already approaching the level required to resolve the current tension.
- This uncertainty can be further reduced by reducing the events' spatial error in the XENONnt detector.

Thank you!!!

- Questions?

Backup I



CEνNS Events (keV⁻¹ton⁻¹year⁻¹)
Efficiency
Energy [keV]
CEνNS Events
XENONnt NR Total Efficiency
0.5
1
5
10
50
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
1.
10^−1
10^−2
10^−3