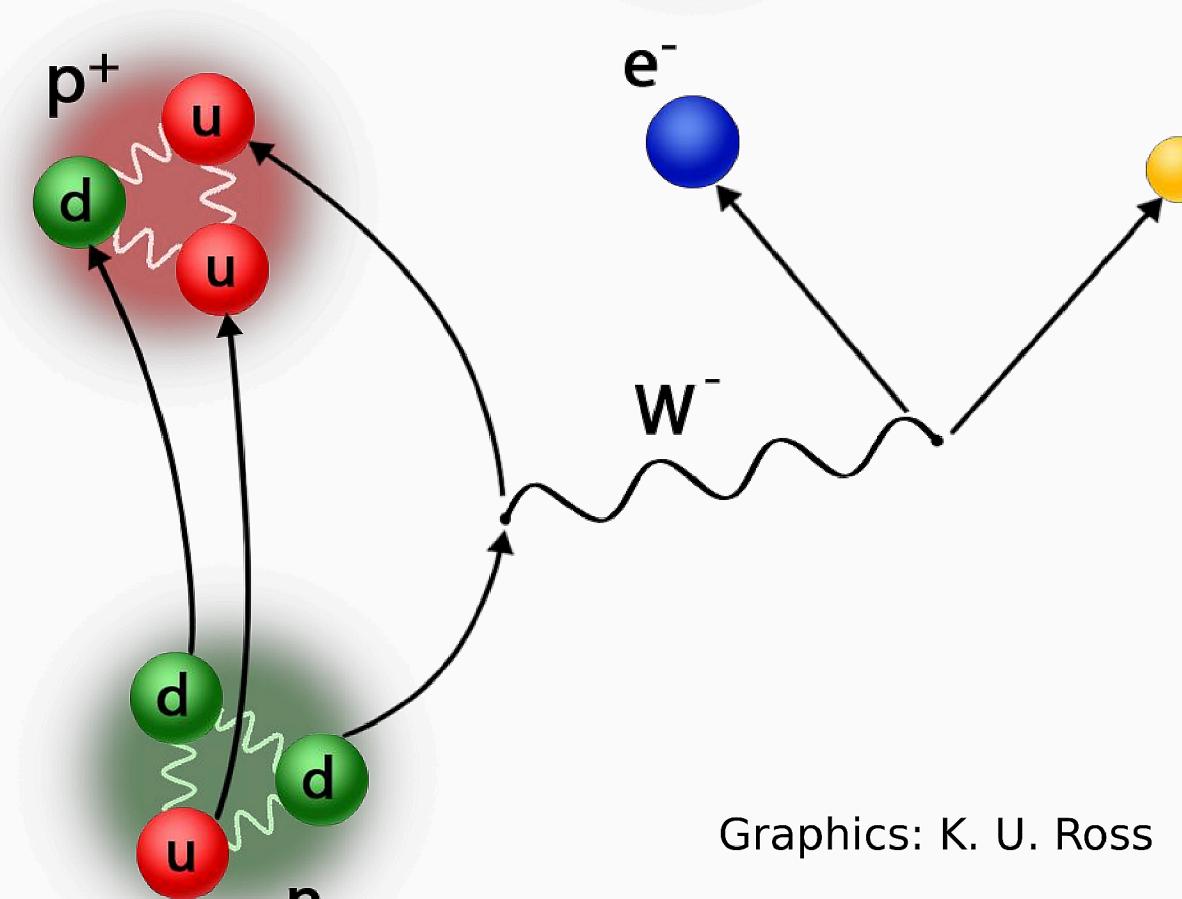
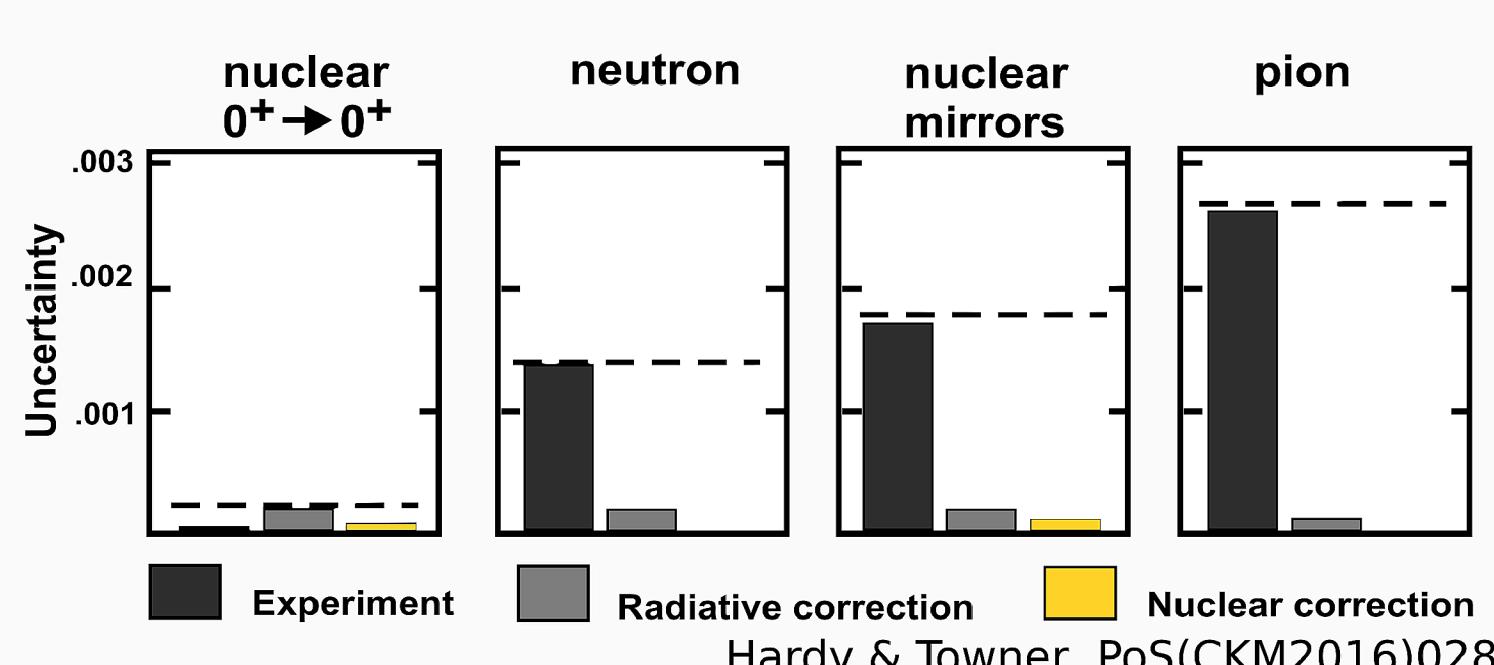


The free neutron lifetime

Prototype for nuclear β -decay



Probing the unitarity of the CKM matrix



Improving the parameters of big bang nucleosynthesis

$$Y_p = 0.24703 \left(\frac{10^{10} \eta}{6.10} \right)^{0.039} \times \left(\frac{N_\nu}{3.0} \right)^{0.163} \times \left(\frac{G_N}{G_{N,0}} \right)^{0.35} \times \left(\frac{\tau_n}{880.3 \text{ s}} \right)^{0.73} \times \text{capture processes}$$

Cyburt et al., arXiv:1505.01076

Current value of the neutron lifetime:

$$\tau_{n,\text{beam}} = 887.7 \pm 1.2 \text{ (stat)} \pm 1.9 \text{ (sys)} \text{ s}$$

A. T. Yue et al., Phys. Rev. Lett. 111, 222501 (2013)

$$\tau_{n,\text{storage}} = 877.7 \pm 0.7 \text{ (stat)} \pm 0.4/0.2 \text{ (sys)} \text{ s}$$

R. W. Pattie Jr. et al., Science 10.1126/science.aan8895 (2018)

Super-allowed $0^+ \rightarrow 0^+$

$$|V_{ud}|^2 = 0.97420(21)$$

Hardy & Towner, PoS(CKM2016)028

$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 ?= 1$$

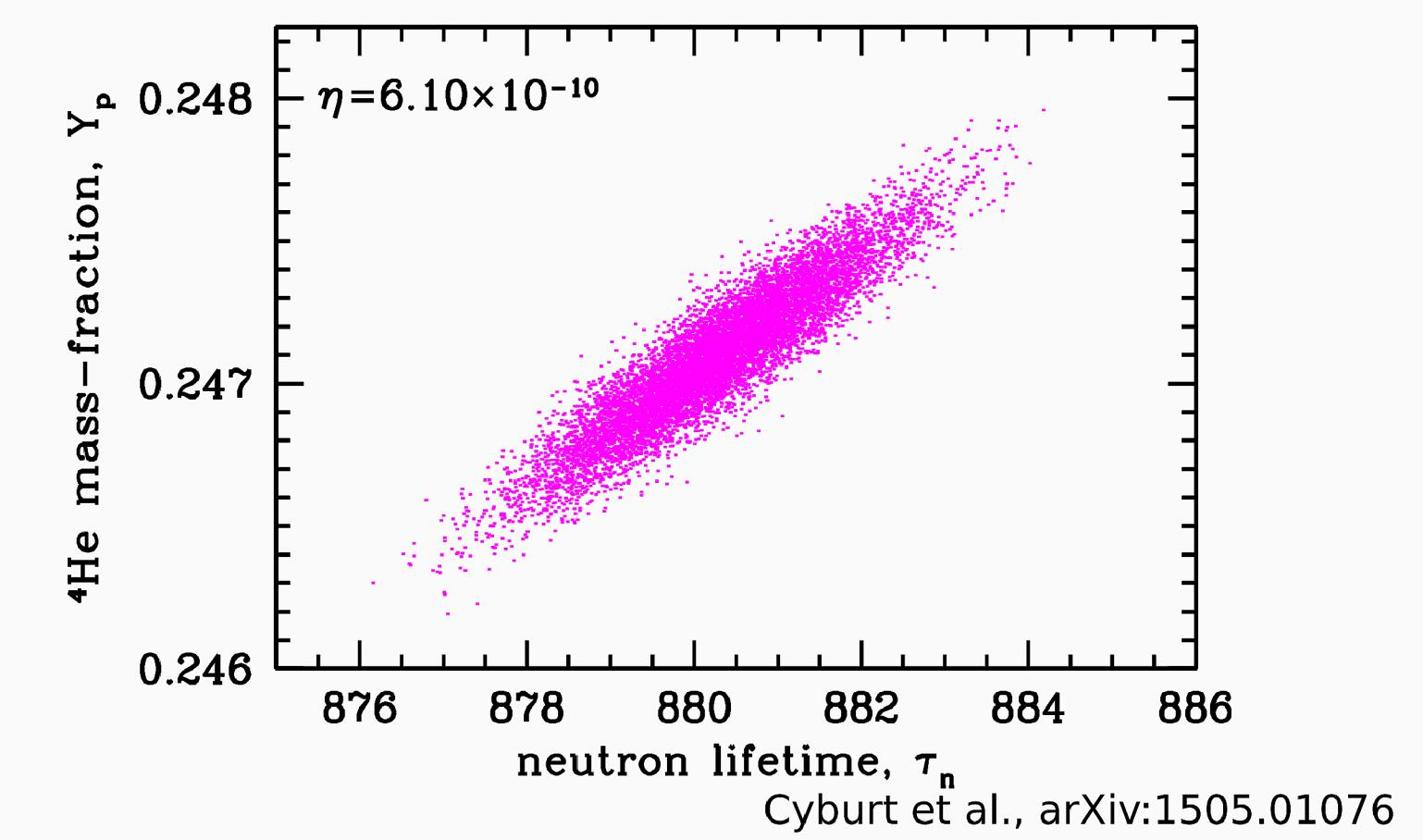
Free neutron decay

$$|V_{ud}|^2 = \frac{4908.7(1.9) \text{ s}}{\tau_n(1+3\lambda^2)}$$

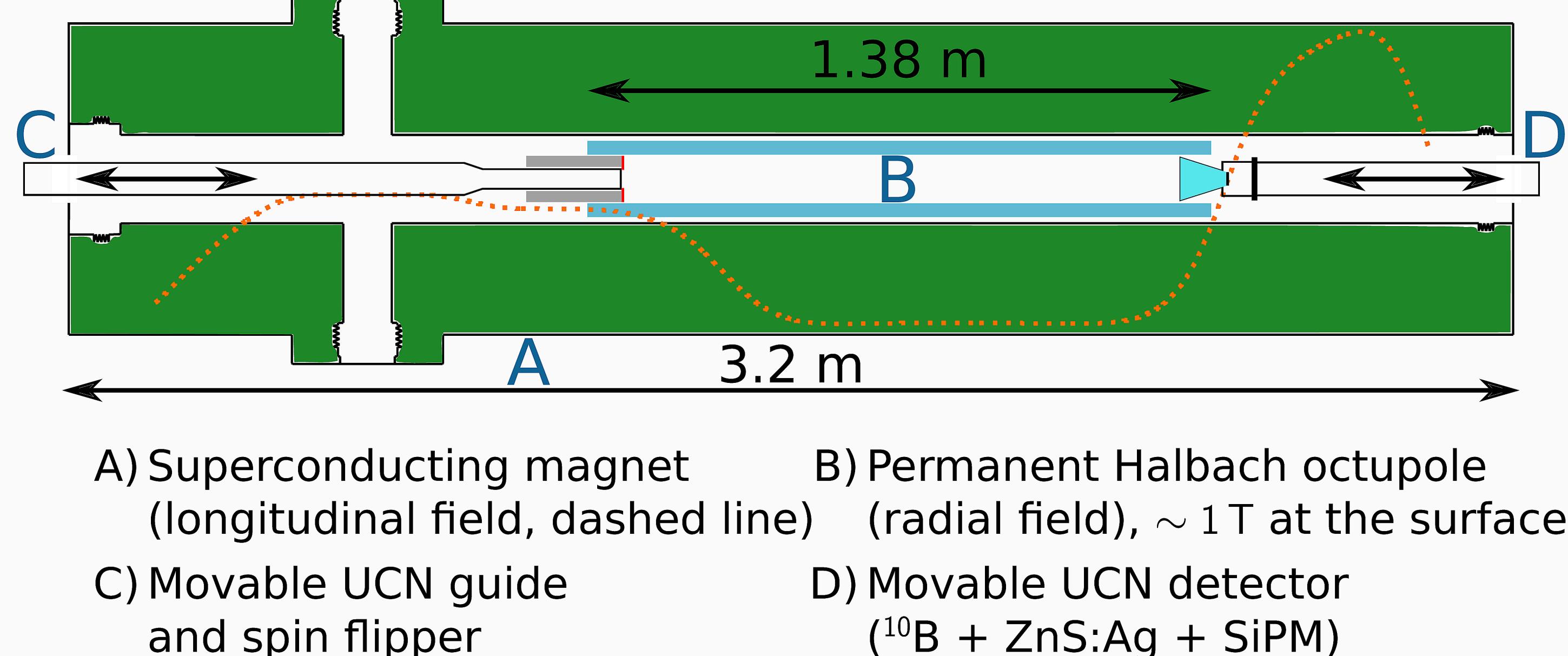
Czarnecki, Marciano and Sirlin
Phys. Rev. Lett. 120, 202002 (2018)

$$\lambda = -1.2732 \pm 0.0023$$

PDG 2019

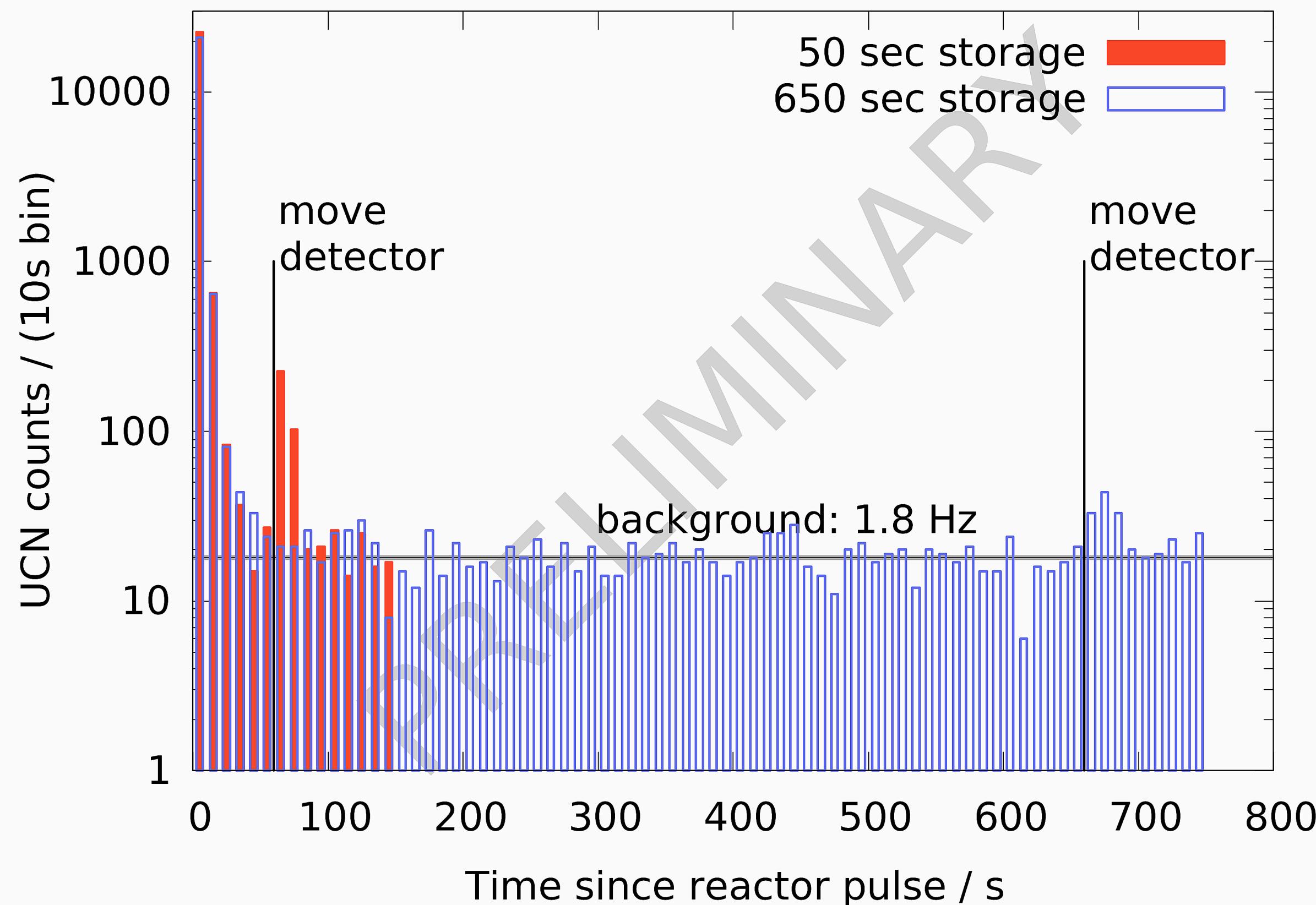


τ SPECT



Status

- Commissioning ongoing, first neutrons stored in τ SPECT in Sept. 2019:

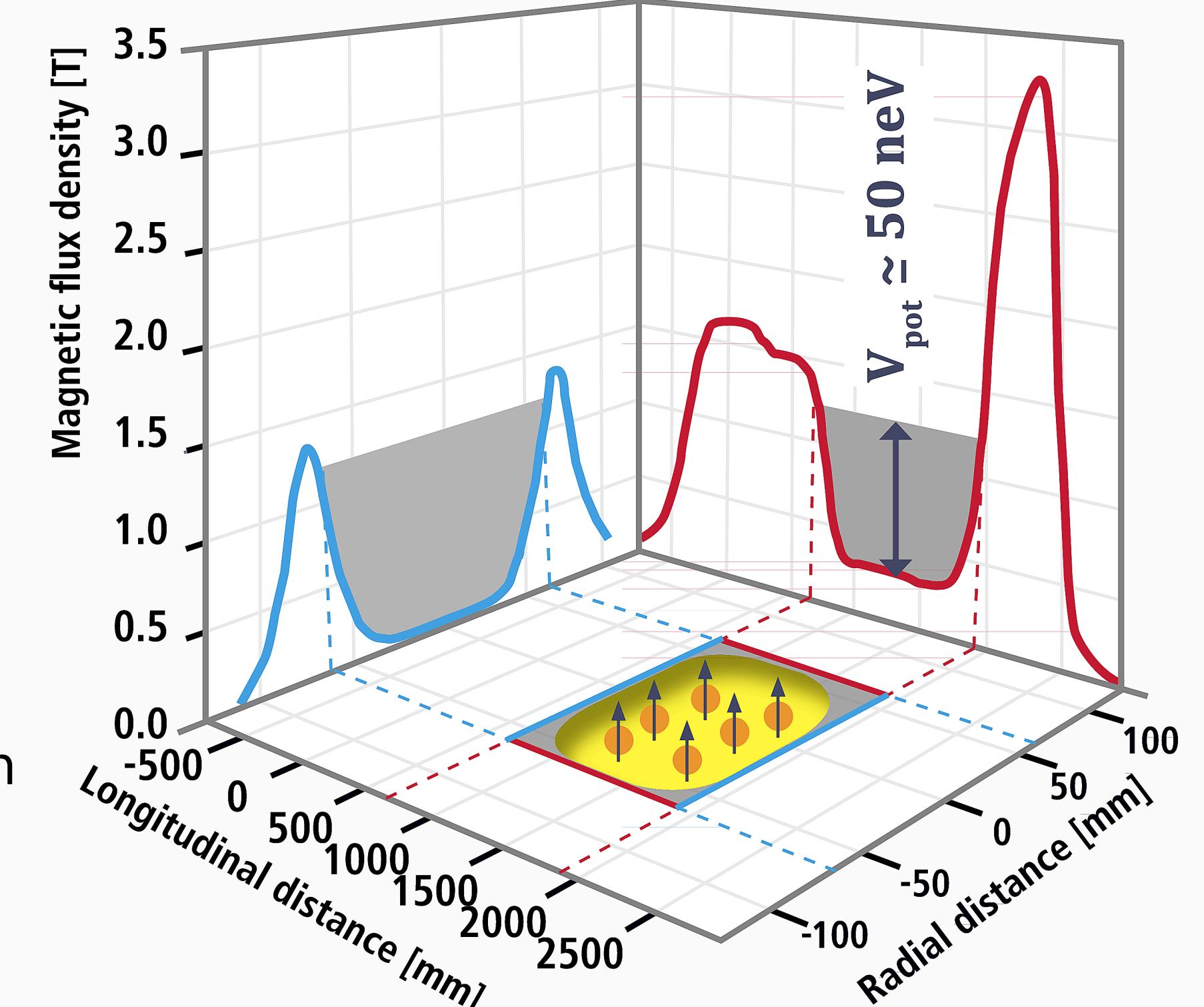


Ultracold Neutrons (UCN)

$$E_{\text{kin}} < 335 \text{ neV} \Leftrightarrow v < 8 \text{ m s}^{-1} \Leftrightarrow T < 4.1 \text{ mK}$$

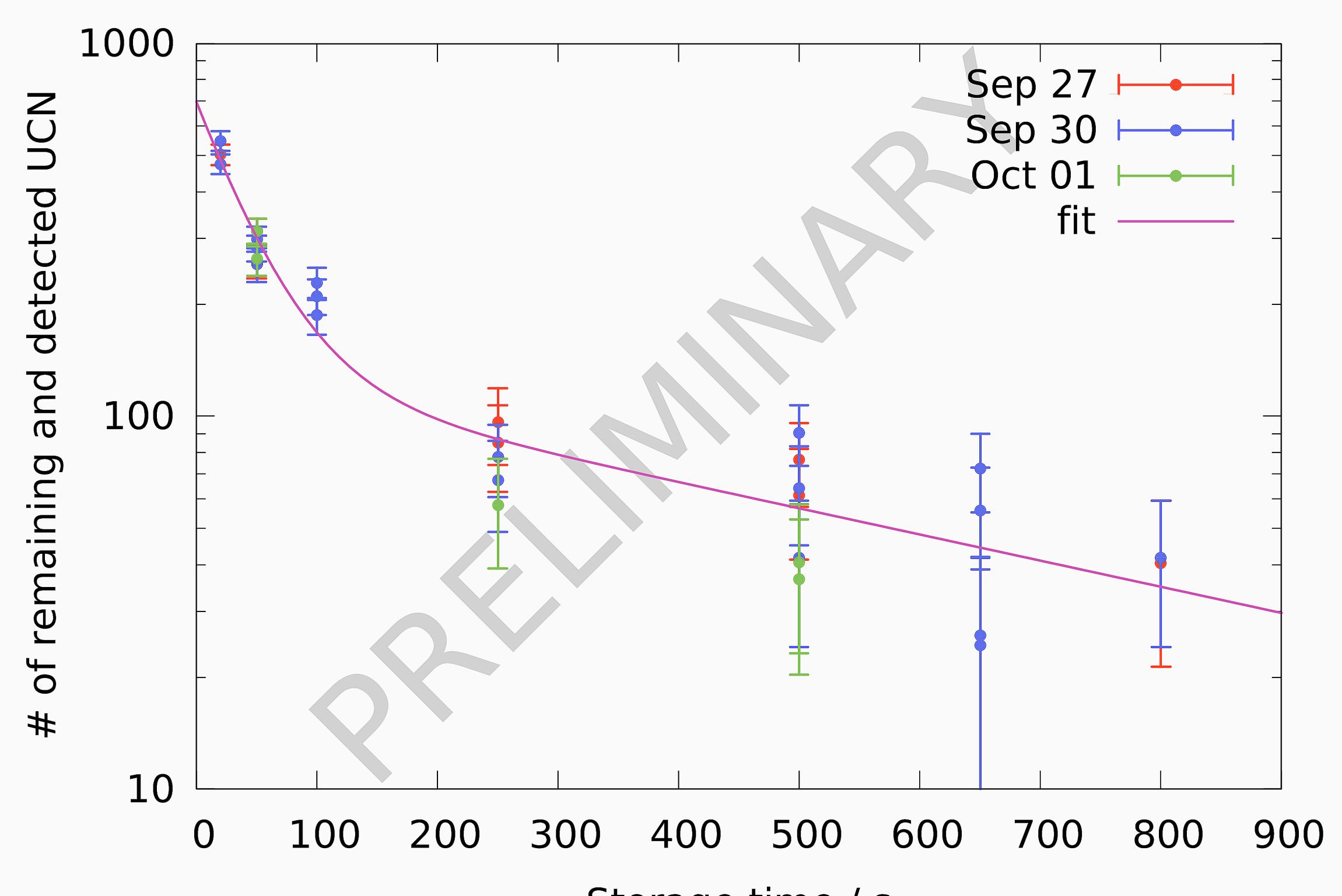
Interactions:

- Strong (Fermi Potential):
 - $V_F \propto \rho b_{\text{coh}}$
 - ${}^{58}\text{Ni}: \sim 335 \text{ neV}$
 - Steel: $\sim 190 \text{ neV}$
- Gravity
 - 102.5 neV m^{-1}
- Magnetism
 - Spin polarization with strong magnetic fields.
 - $\mu_n = -60.3 \text{ neV T}^{-1}$



τ SPECT uses UCN from the pulsed source at beamport D of the research reactor TRIGA Mainz. (see: J. Kahlenberg et al., Eur. Phys. J. A (2017) 53: 226)

UCN Storage



Fit results for two exponentials ($\chi^2/\text{d.o.f.} = 1.56$):

$$A_1 = 570.5 \pm 55.3, \tau_1 = (44.3 \pm 7.2) \text{ s}$$

$$A_2 = 127.0 \pm 31.2, \tau_2 = (619.2 \pm 206.9) \text{ s}$$

Keep in mind:

- Very early data!
- Analysis ongoing & more data incoming

Next Steps

- Characterisation of apparatus performance with neutrons
- Optimisation of filling procedure
- Investigation of outlier events (see plot "UCN Storage")
- Investigation of energy spectrum evolution with time
- Optimisation of detector event reconstruction
- ...

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