Neutron to mirror neutron oscillations at large magnetic fields in beam experiments

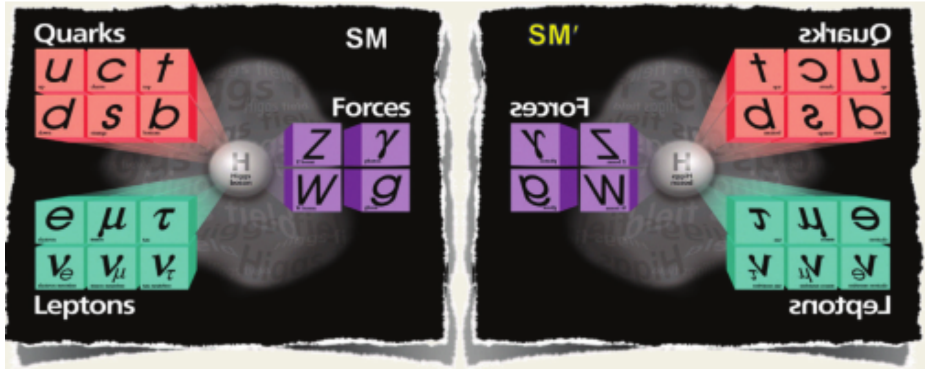
William Sáenz Arévalo - LPC-Caen

on behalf of the collaboration

56th Rencontres de Moriond 2022

Motivation

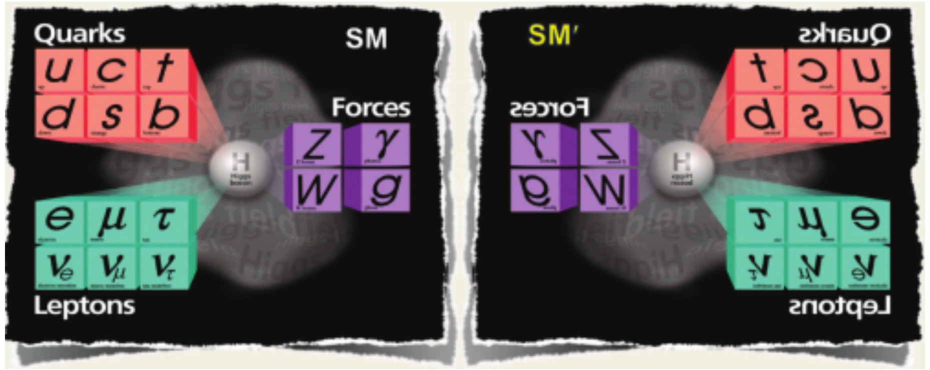
- Mirror (sterile, hidden) matter: candidate to DM
- Exact copy of SM particles: SM’ → P-symmetry restored!
- Mirror and normal matter do not interact through SM interactions besides gravity
- A possible mixing through mass mixing… in particular, for the neutron:

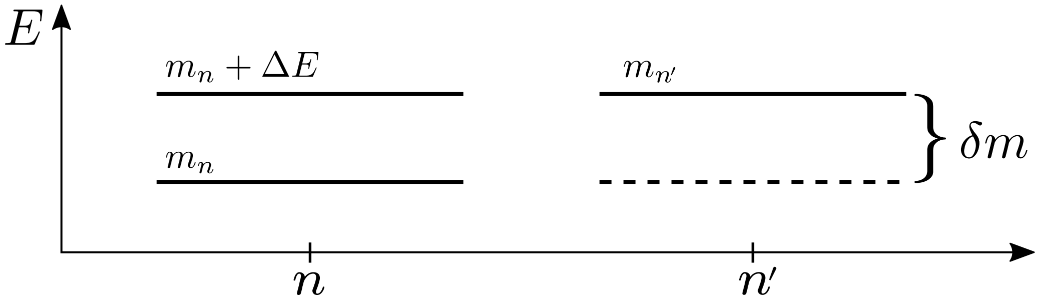


Motivation

- Mirror (sterile, hidden) matter: candidate to DM
- Exact copy of SM particles: SM’ → P-symmetry restored!
- Mirror and normal matter do not interact through SM interactions besides gravity
- A possible mixing through mass mixing… in particular, for the neutron:

$$\hat{H} = \begin{pmatrix} m_n + \Delta E & \epsilon_{nn'} \\ \epsilon_{nn'} & m_n + \delta m \end{pmatrix}$$



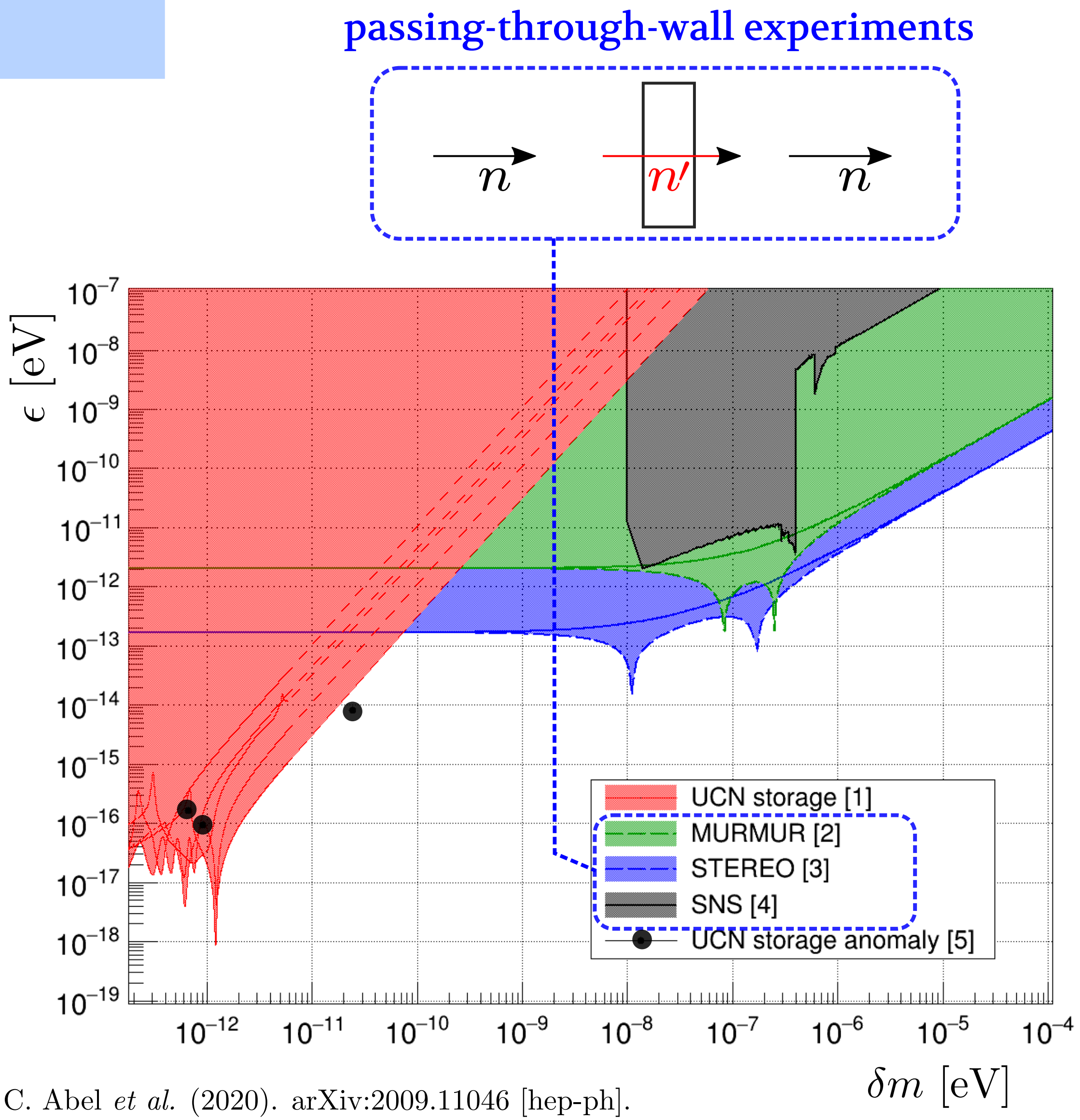


Motivation

- Mirror (sterile, hidden) matter: candidate to DM
- Exact copy of SM particles: SM' → P-symmetry restored!
- Mirror and normal matter do not interact through SM interactions besides gravity
- A possible mixing through mass mixing… in particular, for the neutron:

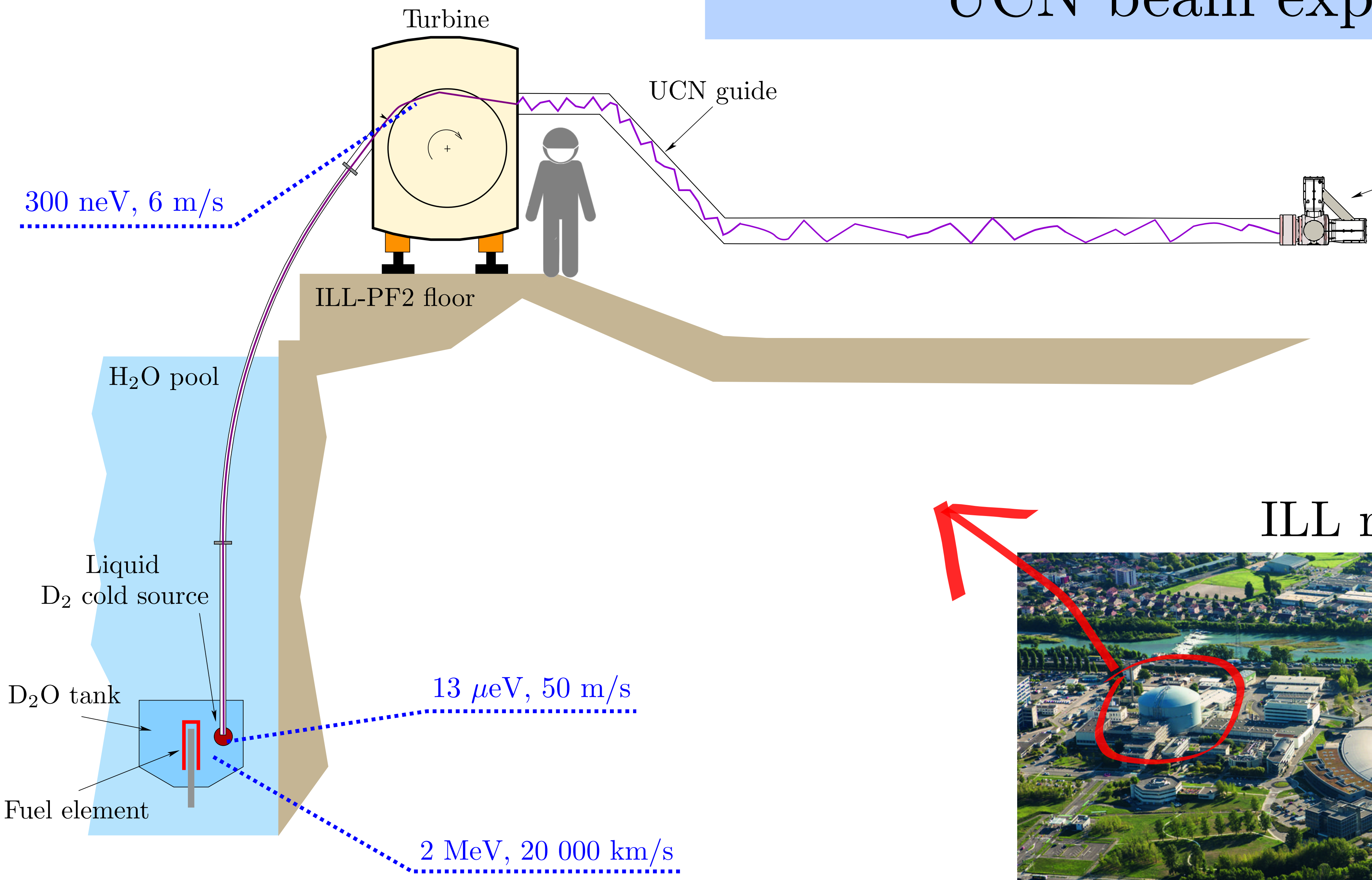
$$\hat{H} = \begin{pmatrix} m_n + \Delta E & \epsilon_{nn'} \\ \epsilon_{nn'} & m_n + \delta m \end{pmatrix}$$

- Anomaly in UCN storage experiments [5]
- Possible solution to the neutron life-time puzzle
- Oscillations at large mass splitting still not tested

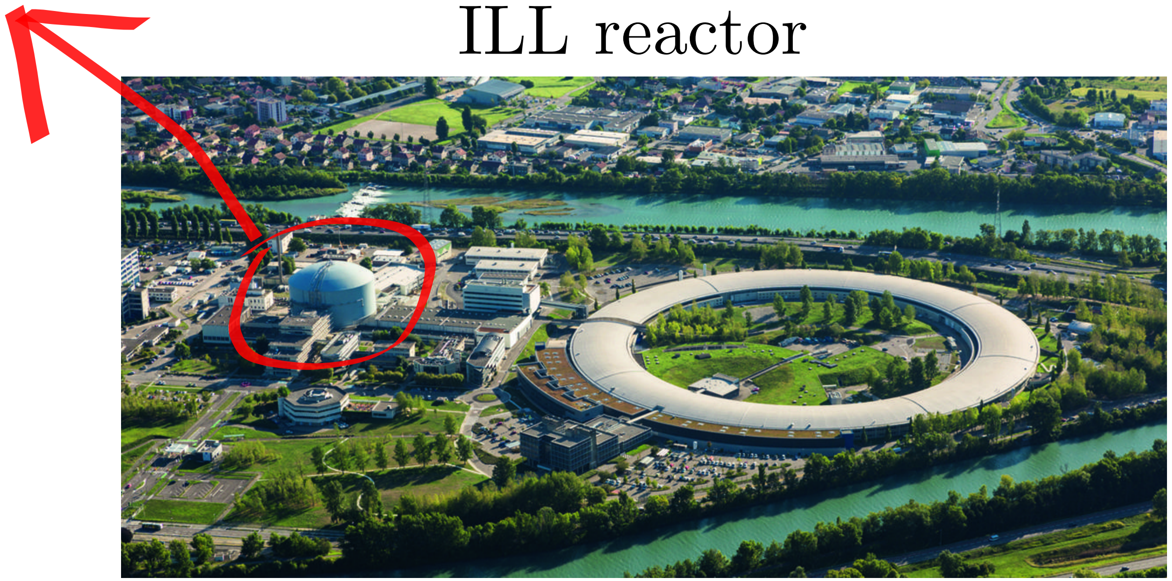


[1] C. Abel *et al.* (2020). arXiv:2009.11046 [hep-ph].
[2] C. Stasser, *et al.* (2021). arXiv:2007.11335 [nucl-ex].
[3] H. Almazán, *et al.* (2021). arXiv:2111.01519 [hep-ex].
[4] L.J. Broussard *et al.*, (2021). arXiv:2111.05543 [nucl-ex].
[5] Z. Berezhiani, F. Nesti, (2012). arXiv:1203.1035 [hep-ph].

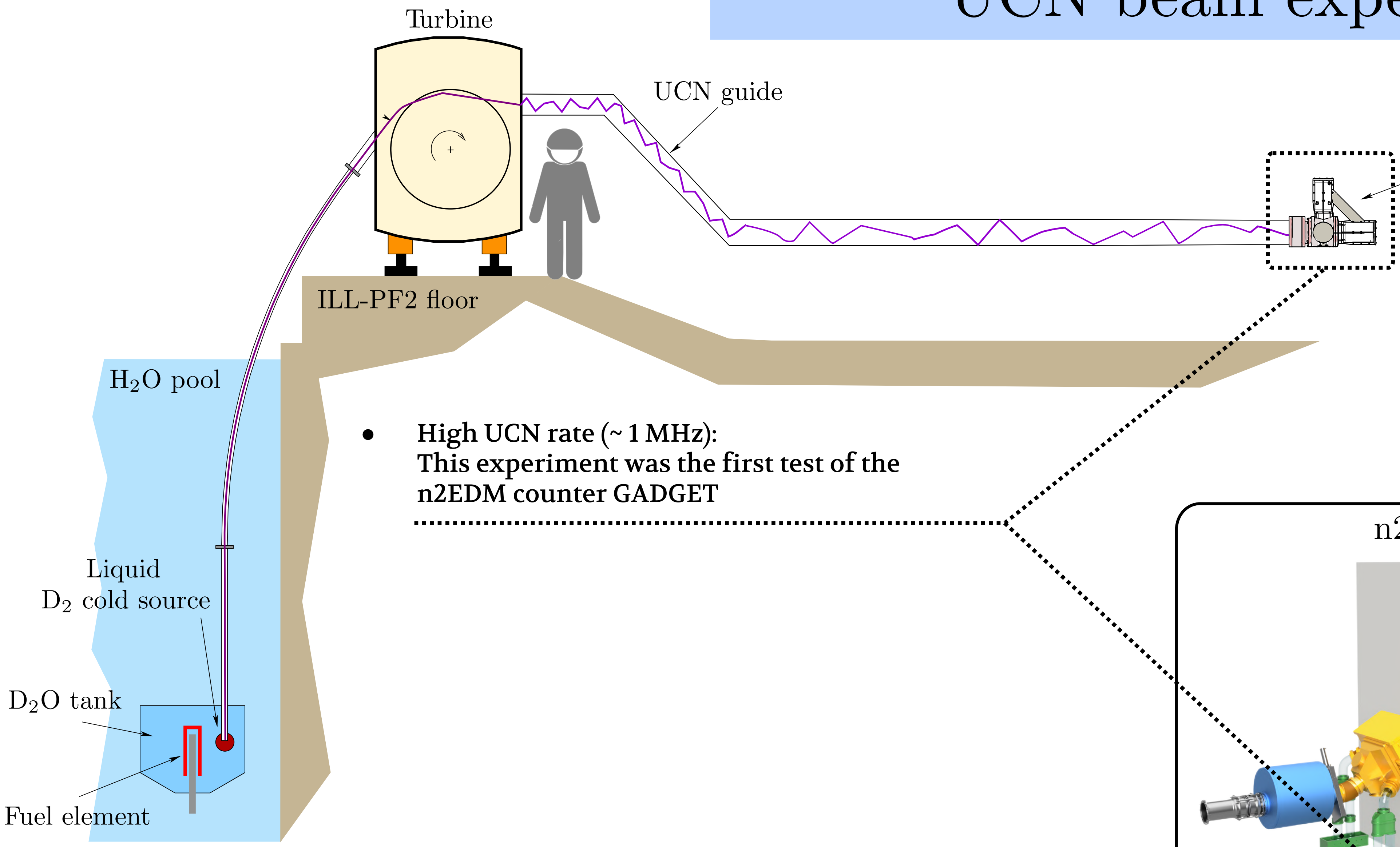
UCN beam experiment



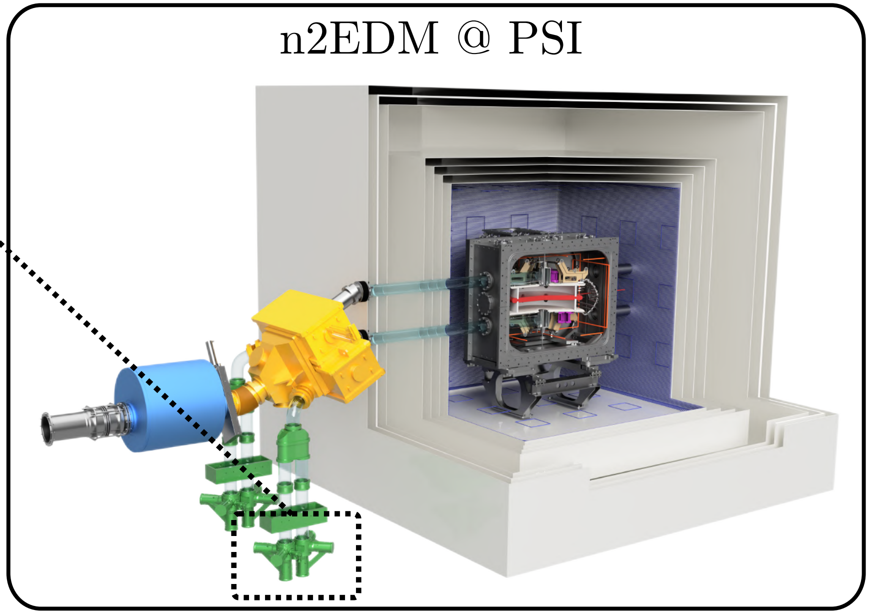
ILL reactor



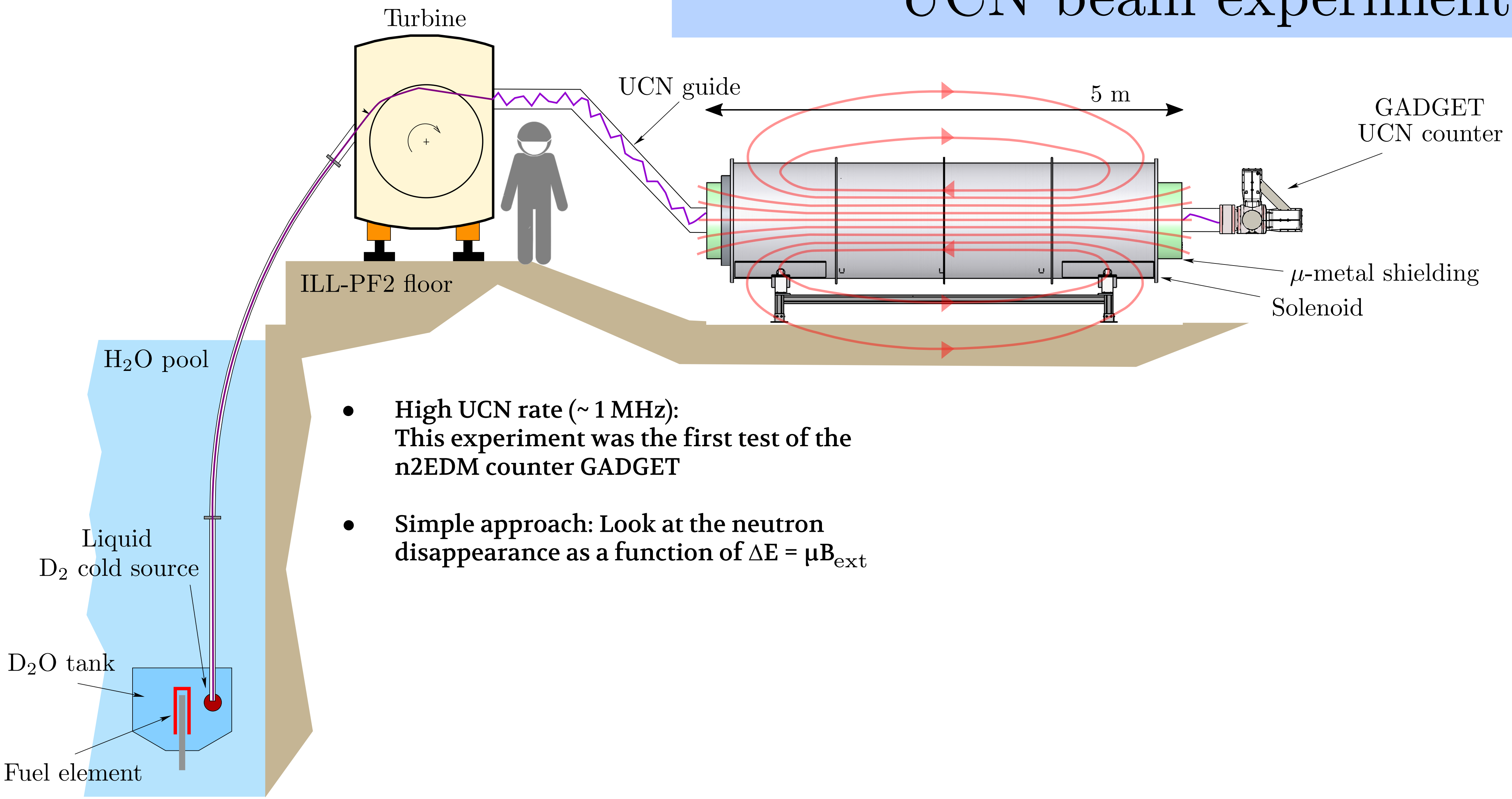
UCN beam experiment



- **High UCN rate (~ 1 MHz):**
  This experiment was the first test of the n2EDM counter GADGET



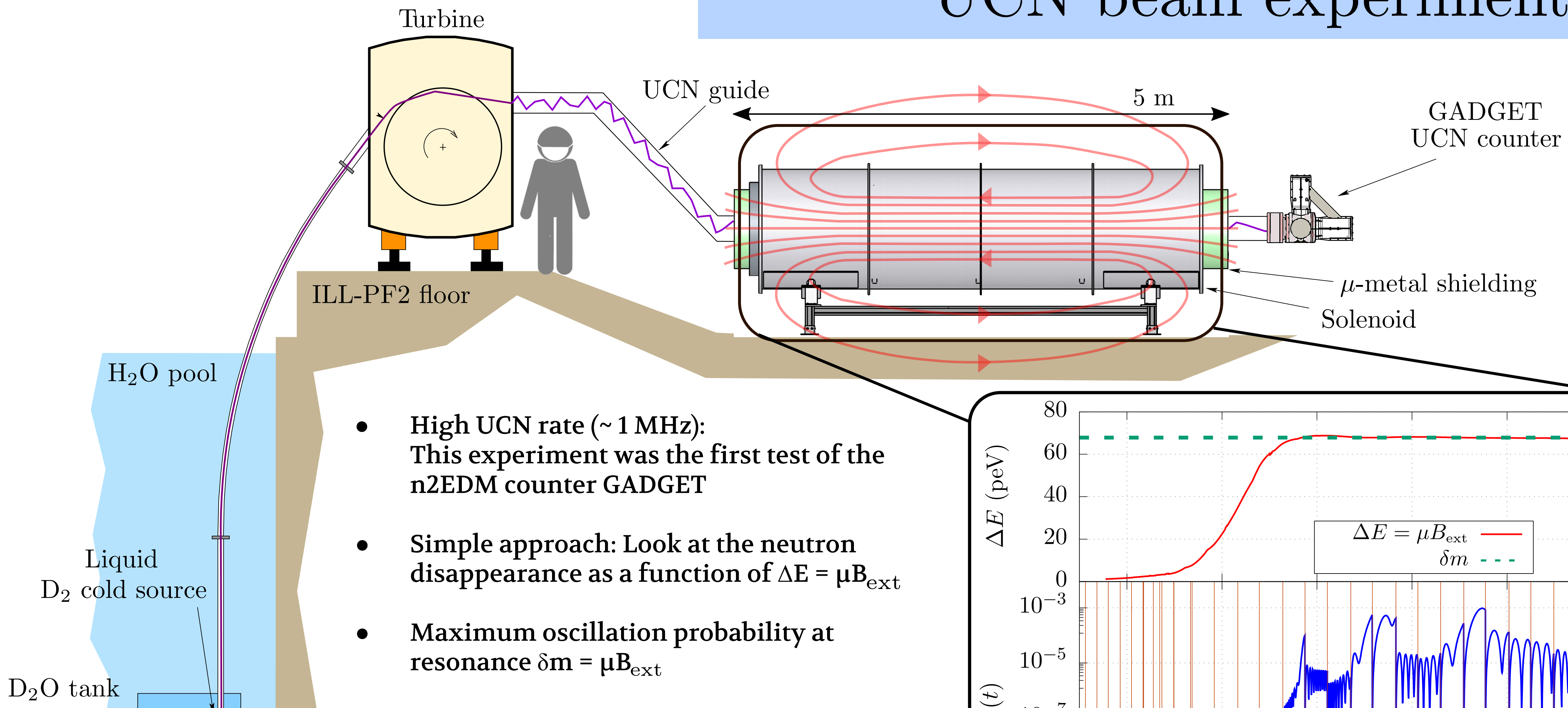
UCN beam experiment



- **High UCN rate (~ 1 MHz):**
  This experiment was the first test of the n2EDM counter GADGET

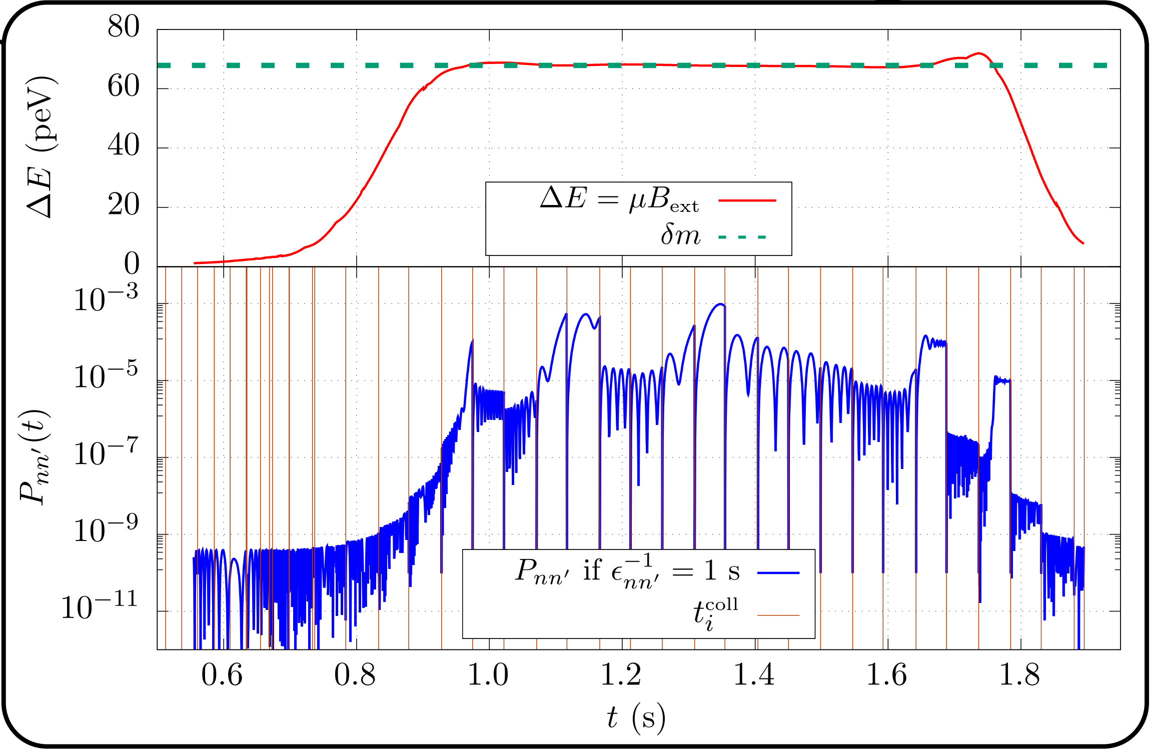
- **Simple approach: Look at the neutron disappearance as a function of $\Delta E = \mu B_{ext}$**

UCN beam experiment



- **High UCN rate (~ 1 MHz): This experiment was the first test of the n2EDM counter GADGET**
- **Simple approach: Look at the neutron disappearance as a function of $\Delta E = \mu B_{ext}$**
- **Maximum oscillation probability at resonance $\delta m = \mu B_{ext}$**

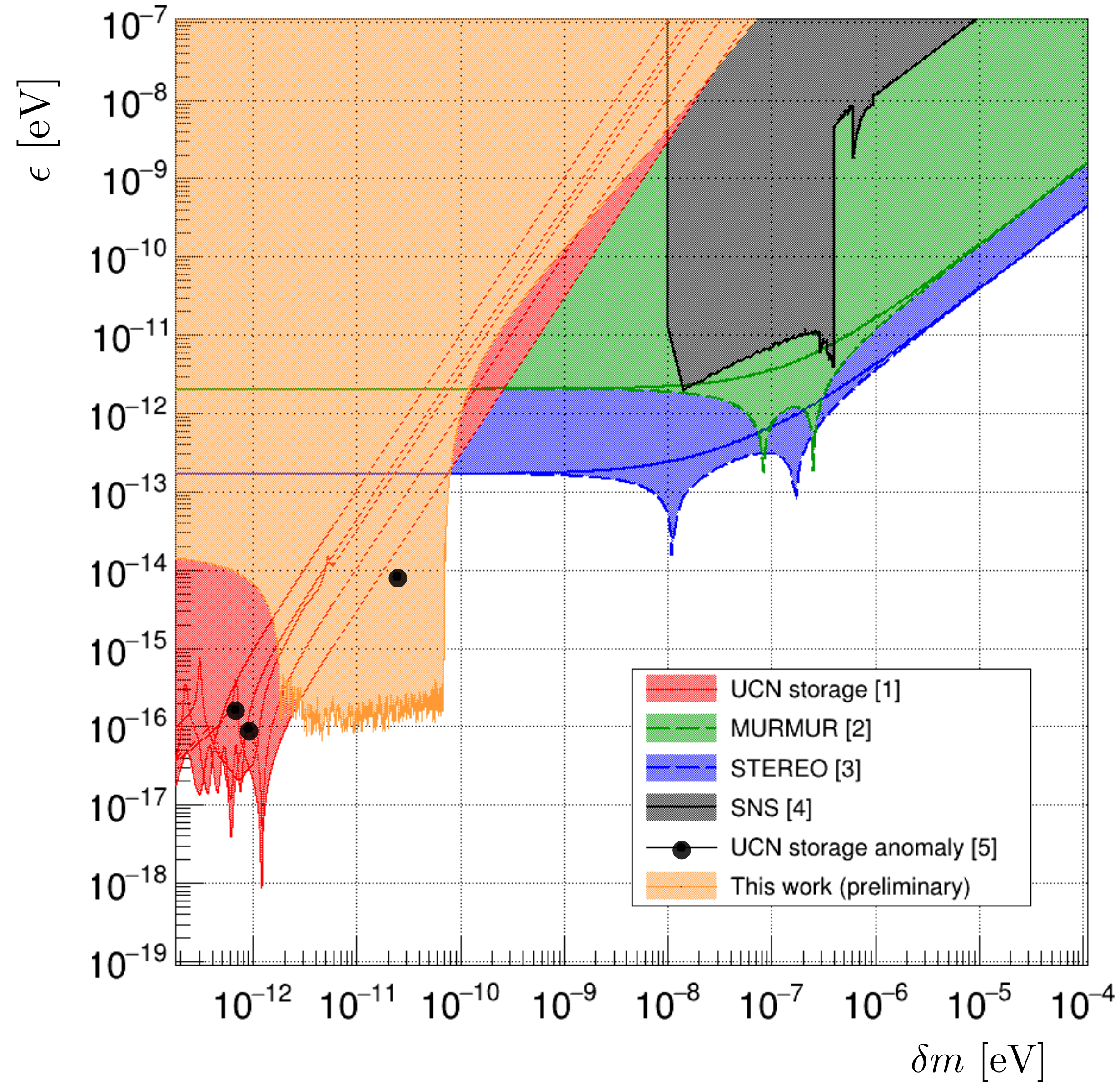
$$P_{nn'}(t) = \frac{4\epsilon_{nn'}^2}{4\epsilon_{nn'}^2 + (\delta m - \mu B_{ext})^2} \sin^2\left(\frac{\sqrt{(\delta m - \mu B_{ext})^2 + \epsilon_{nn'}^2}\, t}{2}\right)$$



Results and perspectives

for Moriond

- No signal, but new exclusion in almost two orders of magnitude of δm: $\epsilon^{-1} < 1$ s
- Anomaly at high δm discarded!
- Future beam experiments would fill the parameter space gap between UCN and passing-through-wall experiments
- New physics could still be found at larger δm

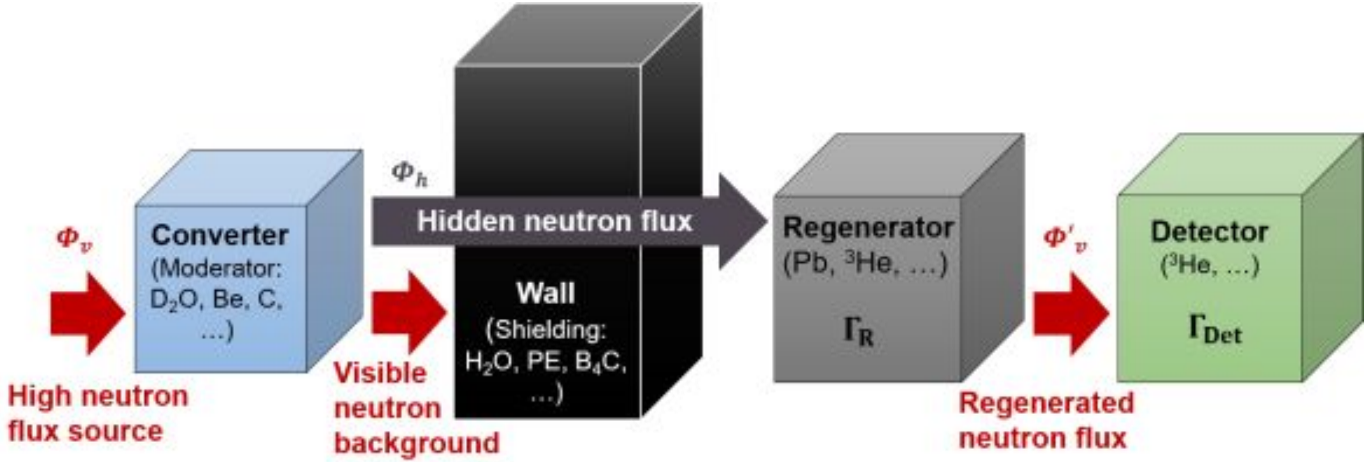


[1] C. Abel *et al.* (2020). arXiv:2009.11046 [hep-ph].
[2] C. Stasser, *et al.* (2021). arXiv:2007.11335 [nucl-ex].
[3] H. Almazán, *et al.* (2021). arXiv:2111.01519 [hep-ex].
[4] L.J. Broussard *et al.*, (2021). arXiv:2111.05543 [nucl-ex].
[5] Z. Berezhiani, F. Nesti, (2012). arXiv:1203.1035 [hep-ph].

Thank you

Spare

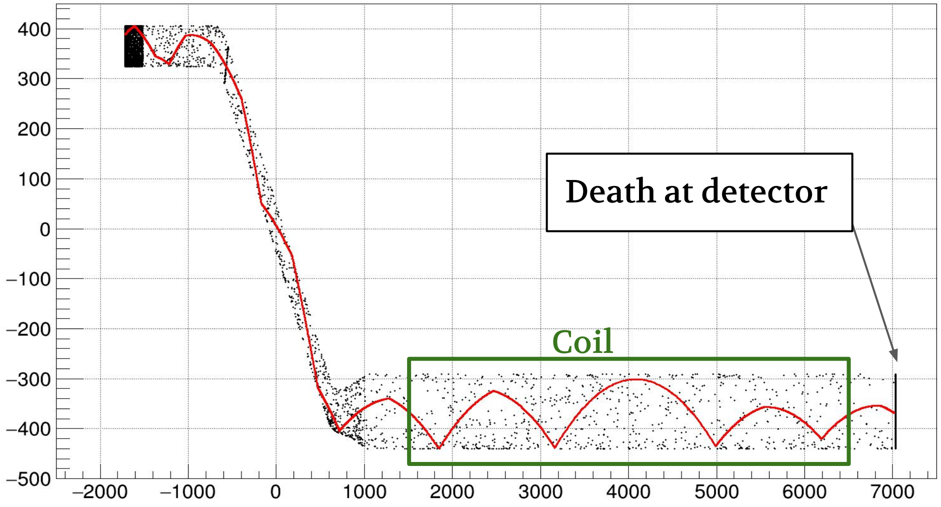
Passing-through-walls neutron experiments

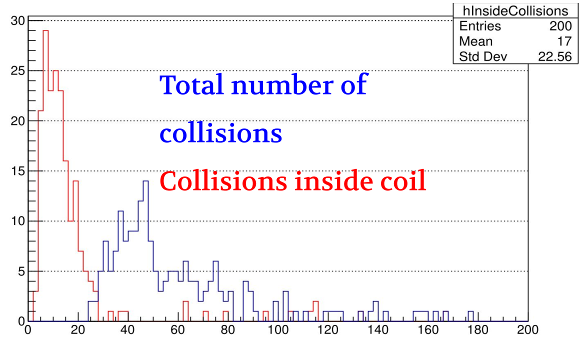


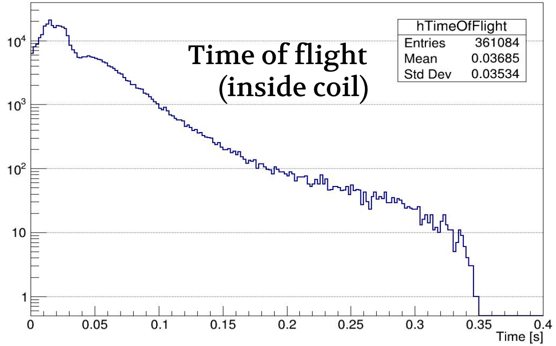
[C. Stasser, *et al.*, Eur. Phys. J. C 81, 17 (2021)]

STARucn - MC track simulations

- Oscillations start when neutrons enter B > 20 μT



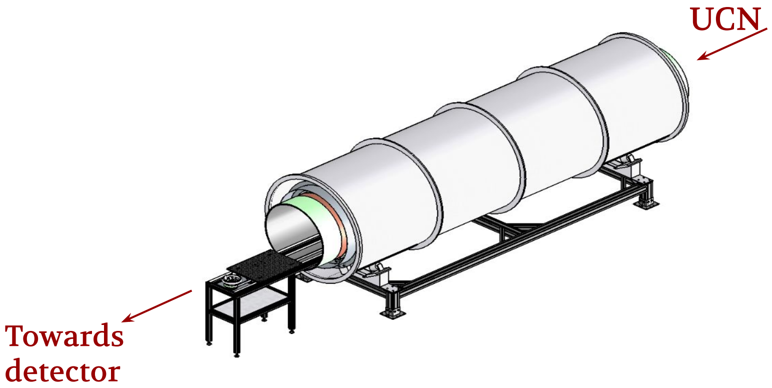




$$\bar{t}_f = \frac{1}{N_n N_{coll}} \sum_{i}^{N_n} \sum_{j}^{N_{coll}} t_{i,j}^{coll} \approx 37\,\mathrm{ms}$$

The solenoid

- N-N’ oscillations with B in 50 - 1000 μT
- Uniform B-field applied at the UCN guide
  - Solenoid
    - StdDev ~ 30 nT with I=1.7 A
    - 4.8 m long
    - 80 cm diameter
  - Compensation coils at both ends (I = 2.5 A)
  - Mu-metal shielding:



GADGET counter

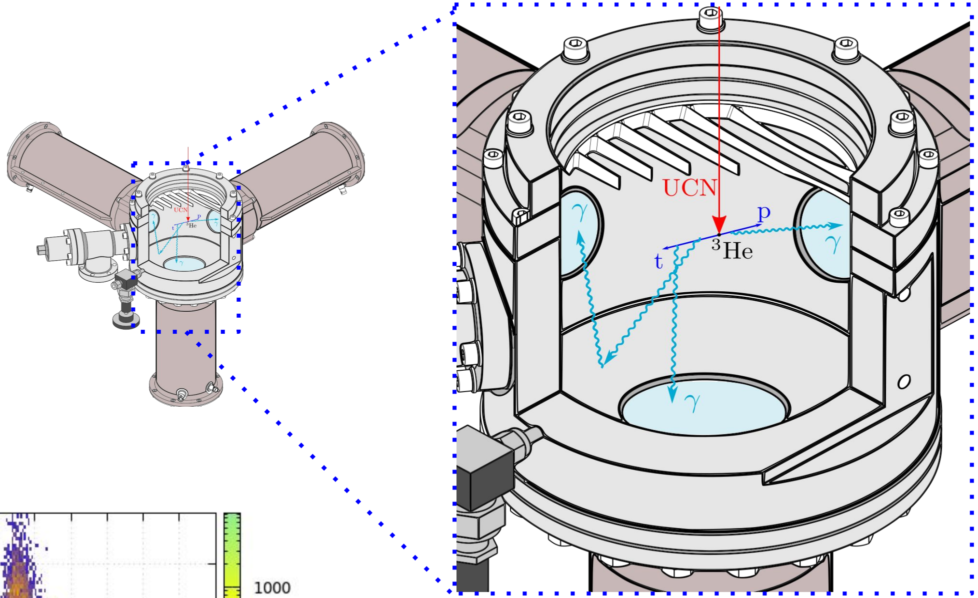
Developed at LPC: ^{3}He and CF_4 gas mixture

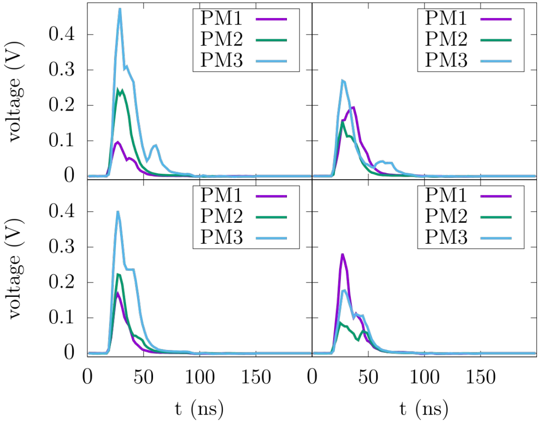
1. UCN absorption

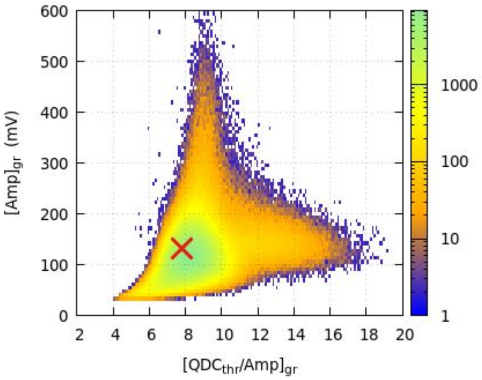
   n + ^{3}He → p (0.57 MeV) + t (0.19 MeV)

2. **CF_4** scintillation due to **p** and **t** ionization/excitation.

3. Light collection by 3 PM tubes working in coincidences







Reactor stability

- Fluctuation in the detector as big as the ones in the reactor power
- Correlation coefficient: $\rho = 0.42$