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PSI UCN vs HFIR CN

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Ayres N.J. et al https://arxiv.org/abs/2111.02794

A Anomaly $\rightarrow$ $UCN \neq Cold$

NIST Beam : $\tau_{trap}(1 + 0.01)$ with cold beam

All traps: τ_{trap} with UCN ($\equiv 1$)

4σ diff

- If PSI will see the nn’ effect with UCN it will be interesting whether HFIR see the same effect with the cold beam
- If PSI will see no nn’ effect it will be still important to know that UCN/Cold limits are set at the same level

B Sensitivity and Signal

UCN @ PSI One fill 450 s, measured number of neutrons $N = 2 \times 10^5$, $\overline{\langle t^2 \rangle} = (0.16s)^2$, 750 collisions per n

$$\boxed{N\,\overline{\langle t^2 \rangle} = 3.84 \times 10^6 \;\; n \cdot s^2} \quad \boxed{P_{res}/n = (t/\tau)^2 = (0.16s/100s)^2 = 2.56 \times 10^{-6}}$$

CN @ HFIR For 450 s, with 10^{10} n/s, $\bar{v}$=800 m/s, L=16 m, $\overline{\langle t^2 \rangle} = (0.02s)^2$

$$\boxed{N\,\overline{\langle t^2 \rangle} = 1.8 \times 10^9 \;\; n \cdot s^2} \quad \boxed{P_{res}/n = (t/\tau)^2 = (0.02s/100s)^2 = 4.0 \times 10^{-8}}$$

$$\frac{HFIR}{PSI} = 469 \quad \leftarrow N\bar{t}^2 \text{ ratio} \qquad\qquad \frac{PSI}{HFIR} = 64 \leftarrow \frac{\text{effect}}{\text{n}} \text{ ratio}$$

$$\text{A = Asymmetry} = \frac{N_B - N_0}{N_B + N_0} = 1.28 \times 10^{-6}\,(PSI);\;\; 2.0 \times 10^{-8}\,(HFIR)$$

Two fills of total 900 s at PSI provide one measurement of A with accuracy of $\delta A \approx \frac{1}{\sqrt{N}} = 2 \times 10^{-3}$.
To reach $1\sigma = A$ accuracy one needs M double fills.
M = 2.4× 10^6 or ~ 70 years

Two time intervals of 450 sec at HFIR provide one measurement with N = 450× 10^{10} each. Accuracy of A will be reduced by factor 2 (?) due to charge integration $\delta A \approx \frac{2}{\sqrt{N}} = 9.5 \times 10^{-7}$.
To reach $1\sigma = A$ accuracy one needs M double 450 s intervals.
M = 2400 or ~ 25 days

We potentially can reach the same limit as PSI for the same B range

Argument C

$$\mathcal{H}_{nn'} = \begin{pmatrix} m + V - iW - i\Gamma/2 + \mu\boldsymbol{\sigma}\mathbf{B} & \epsilon + \eta\boldsymbol{\sigma}(\mathbf{B} + \mathbf{B}') \\ \epsilon + \eta\boldsymbol{\sigma}(\mathbf{B} + \mathbf{B}') & m' + V' - iW' - i\Gamma'/2 + \mu\boldsymbol{\sigma}\mathbf{B}' \end{pmatrix}.$$

It includes $\epsilon = h/\tau$ mixing parameter/transformation time

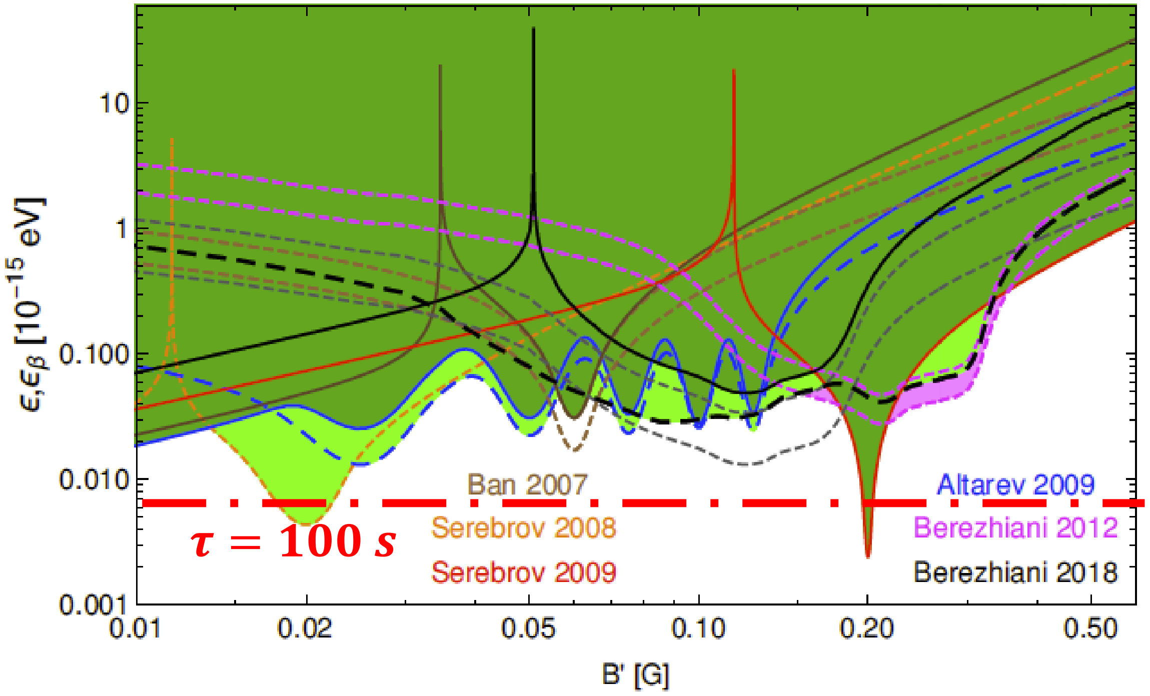
The three effects can be studied separately and independently

1. Effect of resonance at **B=B'** mirror magnetic field
2. Effect of possible mass non-generation $\Delta m = m - m'$ (our SNS experiment)
3. Effect of nTMM η

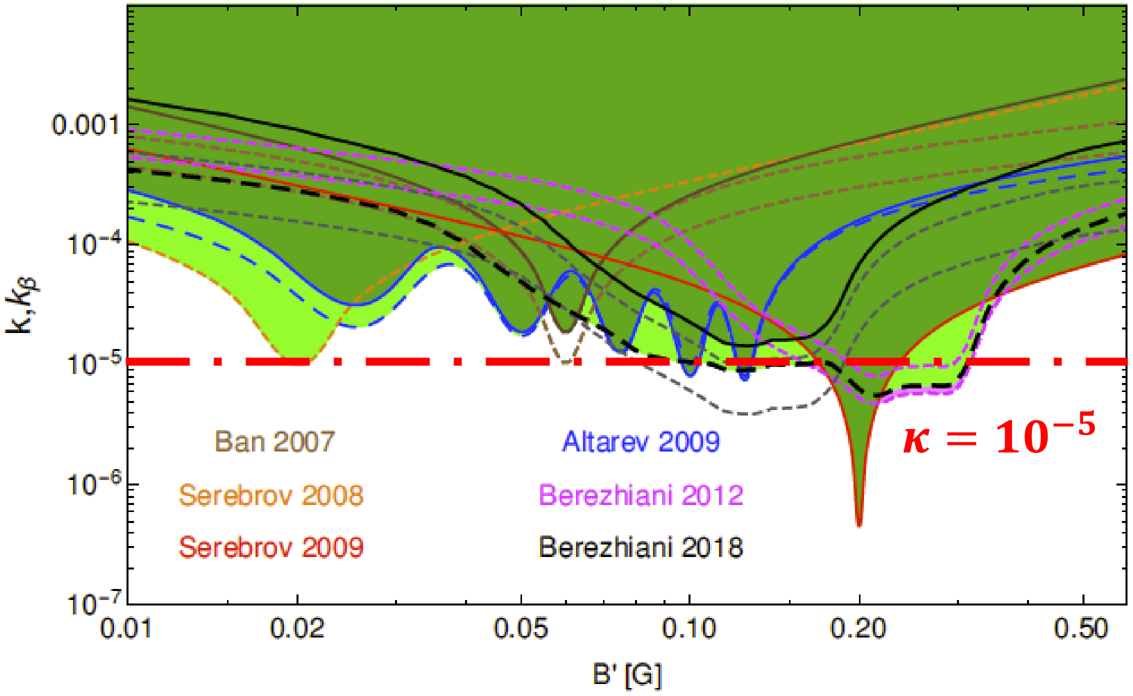
Argument C

From paper https://www.mdpi.com/2624-8174/1/2/21

Current UCN limits in terms of ϵ

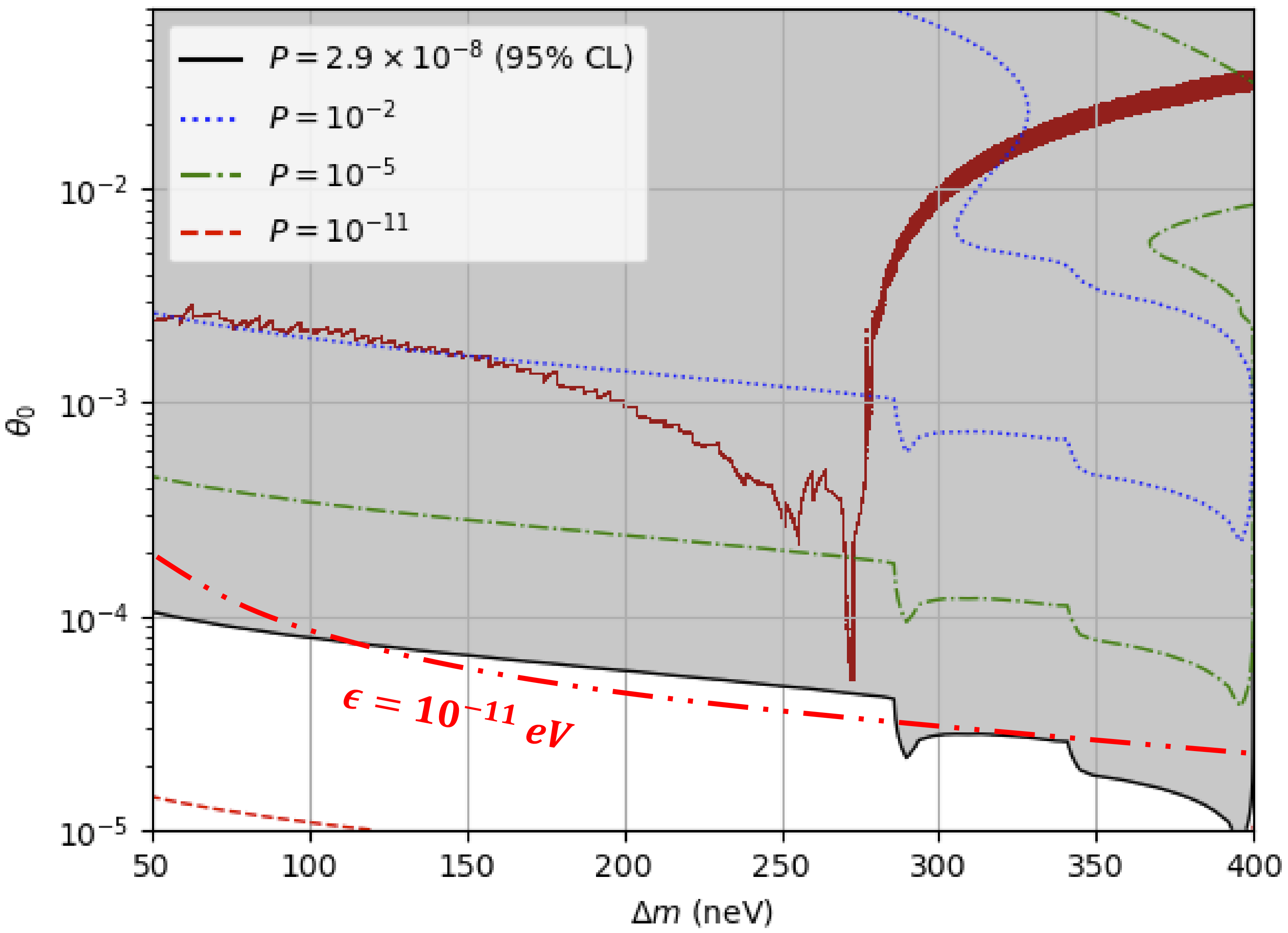


Current UCN limits in terms of $k \cdot \mu_n$



In SNS recent paper https://arxiv.org/abs/2111.05543

Argument C



$$\theta_0 = \frac{\epsilon}{\Delta m}$$

Argument C

1. Effect of B' (PSI in vacuum & HFIR) $\mathcal{H} = \begin{pmatrix} \mu\boldsymbol{\sigma}\boldsymbol{B} & \epsilon_1 \\ \epsilon_1 & \mu\boldsymbol{\sigma}\boldsymbol{B}' \end{pmatrix}$ For $\tau = 100\ s$ $\epsilon_1 = 6.6 \times 10^{-18}$eV

2. Effect of Δm (SNS + HFIR) $\mathcal{H} = \begin{pmatrix} m + \mu\boldsymbol{\sigma}\boldsymbol{B} & \epsilon_2 \\ \epsilon_2 & m' + \mu\boldsymbol{\sigma}\boldsymbol{B}' \end{pmatrix}$ For current SNS limit $\epsilon_2 = 10^{-11}$eV

3. Effect of $nTMM$ (HFIR) $\mathcal{H} = \begin{pmatrix} V - iW + \mu\boldsymbol{\sigma}\boldsymbol{B} & \overbrace{\epsilon_1 + \eta\boldsymbol{\sigma}(\boldsymbol{B} + \boldsymbol{B}')}^{\epsilon_3} \\ \epsilon_1 + \eta\boldsymbol{\sigma}(\boldsymbol{B} + \boldsymbol{B}') & V' - iW' + \mu\boldsymbol{\sigma}\boldsymbol{B}' \end{pmatrix}$ For GP-SANS Exp #1 if $\eta < 10^{-5}\,\mu_n$ $\epsilon_3 < 6 \times 10^{-16}$eV

In the presence of all three effects $\underset{\substack{\uparrow \\ \text{PSI UCN}}}{\epsilon = \epsilon_1} \neq \epsilon_2 \neq \epsilon_3$ ← all can be measured at HFIR/GP-SANS and with a higher sensitivity at ESS/HIBEAM

- We can compare HFIR (cold) with PSI (ucn) e.g. for ϵ_1 if we measure with the same paradigm, e.g. for B and B' effect making same assumptions about Δm and η (nTMM)