The ultracold neutron facility for fundamental physics and the high-sensitivity search for an electric dipole moment of the neutron at the Paul Scherrer Institute.

Bernhard Lauss Paul Scherrer Institute on behalf of the PSI UCN team and the nEDM collaboration INPC 2016 Conference Sept. 2016 Adelaide, Australia

Outline

- the neutron electric dipole moment (nEDM)
- ultracold neutrons (UCN)
- Status of the UCN source at the Paul Scherrer Institute - PSI
- Status of the nEDM search at PSI

Motivation for the nEDM search stems from the oberved Baryon Asymmetry of the Universe

 $s_{13}e^{-i\delta}$

S23C13

 $c_{23}c_{13}$

SM expectation:

 $\frac{n_B - n_{\overline{B}}}{2} \sim 10^{-18}$

 $\begin{array}{cccc} c_{12}c_{13} & s_{12}c_{13} \\ -s_{12}c_{23}-c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23}-s_{12}s_{23}s_{13}e^{i\delta} \\ s_{12}s_{23}-c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23}-s_{12}c_{23}s_{13}e^{i\delta} \end{array}$

n

Sakharov criteria

- 1. Baryon number violation
- 2. C and CP violation

3. Thermal nonequilibrium Observed*:

 $\frac{n_B - n_{\overline{B}}}{2} \sim 10^{-10}$

 n_{v}

*WMAP + COBE (6.19 ± 0.15) x 10⁻¹⁰ [E. Komatsu et al. 2011 ApJS 192]

models with additional CP violation typically also predict (neutron) EDMs

The Whirlpool Galaxy and Companion — M51 O HUBBLESITE.org





Motivation: CP violation & nedm





A non-zero EDM violates P, T and, also CP, assuming CPT conservation.

- Sensitive to QCD -theta term
- Would be first evidence of flavor conserving CP-violation

*J.M. Pendlebury et al., PRD 92 (2015) 092003





the neutron electric dipole moment nEDM - 50+ years perspective





next phase under construction:n2EDM $d_n < low 10^{-27}$ e cm (95% C.L.)stepwise improvement towards $d_n < 5 \times 10^{-28}$ e cm (95% C.L.)



Paul Scherrer Institute -> Switzerland



Paul Scherrer Institute

SwissFEL: **y**

600 MeV p cyclotron p beam current: 2.2 mA 1.3 MW: μ, π

SINQ: n

SLS: γ

Proton cyclotron for medical application: p

UCN: n

Aare

Paul Scherrer Institute -> Switzerland

So akrobatisch sind die Kühe aus dem Fricktal









solid D2 conditioning every day during week test different parameters for 1 week





In 2015 we performed a comparison of all operating UCN sources





An ultracold neutron storage bottle for UCN density measurements

CrossMark

G. Bison ^a, F. Burri ^a, M. Daum ^a, K. Kirch ^{a,b}, J. Krempel ^b, B. Lauss ^{a,*}, M. Meier ^a, D. Ries ^{a,b,**}, P. Schmidt-Wellenburg ^a, G. Zsigmond ^a

journal homepage: www.elsevier.com/locate/nima









 $\sigma(f) = \hbar/2 \alpha T E \sqrt{N}$

best results are still statistically limited

optimize all parameters and most importantly UCN intensity !

- α Visibility of resonance
- T Time of free precession
- N Number of neutrons
- *E* Electric field strength

Ramsey Method



Hg co-magnetometer

UK

PAUL SCHERRER INSTITU











less than 1 neutron is moved from spin up to down in each run

- no simple blinding possible

 Keep un-blinded data in a safe place (encrypted)



Shift the central value by adding an unknown offset

EDM in the range of -1.5 to 1.5E-25 ecm to the data



7000 6000 5000 Counts Nup 4000 3000 2000 1000 29.996 29.997 29.998 29,999 30 30.001 30.002 30.003 30.004 v_0 / Hz

Measurement-Sensitivity 9/2016

UK

nFD

(pc

PB







 $\sigma(f) = \hbar/2\alpha TE\sqrt{N}$





days

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First physics results n/Hg magnetic moment



Physics Letters B 739 (2014) 128-132 Contents lists available at ScienceDirect Physics Letters B www.elsevier.com/locate/physletb



Fig. 4. 1-sigma allowed regions in the γ_n , γ_{Hg} plane. Our final value for the neutron to mercury magnetic moment ratio (18) here labeled as "PSI 2012" forms the diagonal band. The horizontal band is the neutron magnetic moment (1) value from Greene et al. and the vertical band is from the measurement of the mercury magnetic moment (2) by Cagnac.





Fig. 5. Motional false mercury EDM versus the vertical gradient g_z for B_0^{\uparrow} (red up triangles) and B_0^{\downarrow} (blue down triangles). The solid lines correspond to a linear fit, and the dashed line—to the theory discussed in Section 2. The horizontal error bars are smaller than the symbol size.

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Gravitational depolarization of ultracold neutrons: Comparison with data

S. Afach,^{1,2,3} N.J. Ayres,⁴ C. A. Baker,⁵ G. Ban,⁶ G. Bison,¹ K. Bodek,⁷ M. Fertl,^{1,2,†} B. Franke,^{1,2,‡} P. Geltenbort,⁸ K. Green,⁵ W.C. Griffith,⁴ M. van der Grinten,⁵ Z. D. Grujić,⁹ P. G. Harris,^{4,§} W. Heil,¹⁰ V. Hélaine,^{6,‡‡} P. Iaydjiev,^{5,1} S. N. Ivanov,^{5,¶} M. Kasprzak,^{9,**} Y. Kermaidic,¹¹ K. Kirch,^{1,2} H.-C. Koch,^{9,10} S. Komposch,^{1,2} A. Kozela,¹² J. Krempel,² B. Lauss,¹ T. Lefort,⁶ Y. Lemière,⁶ M. Musgrave,⁴ O. Naviliat-Cuncic,^{6,††} J. M. Pendlebury,^{4,*} F. M. Piegsa,² G. Pignol,¹¹ C. Plonka-Spehr,¹³ P. N. Prashanth,¹⁴ G. Quéméner,⁶ M. Rawlik,² D. Rebreyend,¹¹ D. Ries,^{1,2} S. Roccia,¹⁵ D. Rozpedzik,⁷ P. Schmidt-Wellenburg,¹ N. Severijns,¹⁴ D. Shiers,⁴ J. A. Thorne,⁴ A. Weis,⁹ E. Wursten,¹⁴ J. Zejma,⁷ J. Zenner,^{1,2,13} and G. Zsigmond¹







The nEDM collaboration



• 13 Institutions

- 7 Countries
- 48 Members
- 10 PhD students



UK

nED

(pc



Lexington



Summary

- The UCN source at PSI is working well.
 >30 Mill UCN are provided regularly (every 300s) to the experiments. Further optimizations of operating parameters are under way.
- The nEDM experiment at PSI has been data taking continuously since summer 2015.
- New result/limit expected with all 2016 data.
- Construction of next phase apparatus
 n2EDM double chamber setup has started.











thank you

