# International Workshop: Probing Fundamental Symmetries and Interactions with UCN

# Report of Abstracts

# M O N D A Y

Abstract ID : **61**

# Electric Dipole Moments: A Look Beyond the Standard Model

## Abstract content

Searches for the permanent electric dipole moments of atoms, nucleons, and nuclei provide one of the most powerful probes of CP-violation beyond the Standard Model. In this talk, I survey the opportunities for discovering BSM CP-violation with the present and next generation EDM searches; discuss the complementary of searches using different systems; and highlight the implications of these searches for explaining the origin of the cosmic matter-antimatter asymmetry.

**Primary author(s) :** Prof. RAMSEY-MUSOLF, Michael (University of Massachusetts Amherst)

**Presenter(s) :** Prof. RAMSEY-MUSOLF, Michael (University of Massachusetts Amherst)

Abstract ID : **67**

# Searches for the electric dipole moment of the neutron

## Abstract content

Searches for a finite, permanent electric dipole moment of the neutron (nEDM) have provided major constraints for theories of CP violation for many decades. A non-zero nEDM has not been found yet and the present best limit dates back from an experiment more than a decade ago. There is a number of nEDM projects under way with the goal to improve the experimental sensitivity by one order of magnitude or more. An overview of the ongoing and some possible future activities will be given.

**Primary author(s) :** KIRCH, Klaus (ETH Zürich and PSI Villigen, CH)

**Presenter(s) :** KIRCH, Klaus (ETH Zürich and PSI Villigen, CH)

Abstract ID : **70**

# Nucleon charges and probing novel CP violation via neutron EDM

## Abstract content

I will first present high statistics results for the iso-vector charges of the nucleon and their importance for probing new scalar and tensor interactions at the TeV scale. After an introduction to the quark EDM and quark chromo EDM operators that arise in an effective field theory analysis of novel CP violation in BSM theories, I will present results for the quark EDM and describe the status of lattice calculations of the quark chromo EDM.

**Primary author(s) :** Dr. GUPTA, Rajan (Los Alamos National Lab)

**Presenter(s) :** Dr. GUPTA, Rajan (Los Alamos National Lab)

Abstract ID : **40**

# Search for the electric dipole moment of the neutron at PSI

## Abstract content

The existence of a finite neutron electric dipole moment (nEDM) larger than the electro-weak Standard Model (SM) prediction would indicate a new source of CP violation, probe many theories beyond the SM and might help to understand the matter–antimatter asymmetry of the Universe. We present the current status of the experiment searching for the nEDM with the substantially upgraded apparatus which was previously used to obtain the current upper limit of 3.0E-26 ecm at the Institute Laue–Langevin (ILL) [C.Baker et al., PRL 97, 131801 (2006), J.M. Pendlebury et al., PRD 92, 092003 (2015)] and is now located at the new source of ultracold neutrons (UCN) at the Paul Scherrer Institute.

The measurements are performed using Ramsey's method of separated oscillatory fields in a very stable magnetic field environment with much improved control of systematics effects. The nEDM collaboration improved the sensitivity of the measurements due to an increase of the number of UCN detected after storage and the implementation of an optimization of the magnetic field homogeneity. The currently accumulated raw sensitivity is just below $\sigma(dn) = 1.7E{-}26$ ecm after 124 days of data taking in 2015.

The ongoing data analysis takes into account recent developments in the understanding of the effects of gravity on UCN depolarization [S. Afach et al., PRD92, 052008 (2015)] and is complemented by results from a novel UCN spin-echo method which permits the reconstruction of the UCN energy spectrum after storage, and an improved determination of the vertical magnetic-field gradient [S. Afach et al., PRL115, 162502 (2015)].

**Primary author(s) :** Dr. BONDAR, Vira (Paul Scherrer Institute)

**Presenter(s) :** Dr. BONDAR, Vira (Paul Scherrer Institute)

**Comments:**

On behalf of the nEDM Collaboration

Abstract ID : **38**

# New effort to develop an nEDM experiment at LANL

## Abstract content

Research and development work at LANL towards a new neutron EDM experiment using the LANL UCN source with a sensitivity goal of several x 10-27 e-cm is currently ongoing. The initial focus of this effort is an upgrade of the UCN source and a demonstration that a sufficient number of UCN can indeed be stored in a nEDM measurement cell. In this talk, the concept of the experiment and current status of this R&D will be presented.

**Primary author(s) :** Dr. ITO, Takeyasu (Los Alamos National Laboratory)

**Presenter(s) :** Dr. ITO, Takeyasu (Los Alamos National Laboratory)

Abstract ID : **71**

# Present status and future prospects of nEDM experiment of PNPI-ILL-PTI collaboration

## Abstract content

New result of nEDM experiment (0.54 +_3.04) 10^-26 e cm or /d/< 5.5 10^-26 e cm at 90% ( C.L.) will be presented. The future plan is to increase sensitivity in a few times at ILL reactor with turbine source. The long-term plane to increase sensitivity in more order of magnitude with new UCN source at WWR-M reactor will be discussed also.

**Primary author(s) :** Prof. SEREBROV, Anatoly (PNPI)

Abstract ID : **19**

# Cryogenic Magnetic Shielding R&D for nEDM at SNS

## Abstract content

The nEDM experiment at the Spallation Neutron Source aims to search for a neutron electric dipole moment (nEDM) with a sensitivity of < 5 e-28 e-cm. Polarized ultracold neutrons will precess in a 30 mG holding magnetic field while the electric field is varied; a non-zero neutron EDM will appear as a variation in the precession frequency correlated with the electric field. Magnetic field gradients in the detector must be reduced below 3 ppm/cm relative to the holding field in order to remove false signal from the systematic geometric phase effect and to increase the neutron polarization lifetime. I will discuss two prototype magnet systems we have constructed. The first uses a cos(theta) coil operated at the design field inside an open-ended superconducting lead shield; it has demonstrated gradients nearly satisfying the design requirement. In the second prototype, both the cos(theta) coil and lead shield are operated inside a cryostat, allowing both to be cooled via exchange gas to superconducting temperatures and enabling the lead shield to nearly fully enclose the magnet.

**Primary author(s) :** Dr. SLUTSKY, Simon (California Institute of Technology)

**Presenter(s) :** Dr. SLUTSKY, Simon (California Institute of Technology)

Abstract ID : **37**

# An apparatus for studying ultracold neutron storage time at cryogenic temperatures for the SNS nEDM experiment

## Abstract content

Material bottles for ultracold neutrons (UCN) have important applications to the development of new generations of neutron electric dipole experiments. An apparatus has been developed at the Los Alamos National Lab (LANL) UCN source to study material bottles at cryogenic temperatures for the SNS nEDM experiment. Our recent measurements of the UCN lifetime in a material bottle coated with deuterated polystyrene and deuterated tetraphenyl butadiene has shown that this lifetime is highly dependent on the cooling procedure used. These procedure-dependent results could be explained by contamination on the coating surface. I will describe the cryogenic apparatus, the experimental results, and their interpretation.

**Primary author(s) :** Dr. TANG, Zhaowen (Los Alamos National Lab)

**Presenter(s) :** Dr. TANG, Zhaowen (Los Alamos National Lab)

**Comments:**

Presenting for the SNS nEDM collaboration

Abstract ID : **49**

# Measurement cells of the SNS nEDM experiment

## Abstract content

(on behalf of the SNS nEDM experiment)
The Spallation Neutron Source (SNS) nEDM experiment will use 3L rectangular measurement cells filled with superfluid helium at 0.3-0.5K with a $\sim 10^{-10}$ fraction of polarized $^3$He. These cells are made from 13 mm thick UV-transparent acrylic plates, swing-coated with a mixture of deuterated polystyrene and deuterated tetraphenyl butadiene, and then glued together with deuterated acrylic cement deposited with robotic dispenser. The experiment requirements the cells to be: non-magnetic, non-conducting, provide fluorescence at the inner surface, optically transparent, cryogenic-friendly, have long UCN storage times, and polarized 3He friendly.

The successful production of full-sized cells, as well as how these cells address each of the above requirements, will be presented. Focus will be given on recent UCN storage tests of several cells measured between 90K to 20K. These results demonstrate the cryogenic robustness of these cells and UCN loss f-factors of ˜2E-5, better than beryllium at similar temperatures. A previous problem of gaps or uncovered patches exposed on the inside of the cell has been resolved. Exploratory work on polymer coatings that could improve our cells further will also be presented.

**Primary author(s) :** Dr. LEUNG, Kent (North Carolina State University)

**Presenter(s) :** Dr. LEUNG, Kent (North Carolina State University)

Abstract ID : **30**

# The new magnetic field optimisation procedure of the nEDM experiment at PSI

## Abstract content

The nEDM experiment at the Paul Scherrer Institute (PSI) is currently the most sensitive in the world. One of the main improvements that made this possible is the new algorithm for the optimisation of the magnetic field. The procedure makes use of the Cs magnetometer array that is installed outside of the precession volume of the neutrons to find the optimal set of currents for the 30 'trim' coils that are installed around the setup.
First, the field generated by each of the 30 coils is characterised by running the Cs magnetometers in variometer mode, thus obtaining vector information. Next, the shape of the instantaneous main magnetic field is measured. This information is then used by a smart optimisation algorithm that prioritises the longitudinal homogeneity of the field over the transversal components, but moderates the total field that is created.
The magnetic field configurations thus obtained result in a Ramsey contrast (visibility) of typically 0.75 to 0.8, whereas previously the experiment was ran at a visibility of 0.55 to 0.60. This effectively increases the sensitivity of our experiment by about 30%.

**Primary author(s) :** Ms. WURSTEN, Elise (Institute for Nuclear and Radiation Physics, KU Leuven)

**Presenter(s) :** Ms. WURSTEN, Elise (Institute for Nuclear and Radiation Physics, KU Leuven)

Abstract ID : **42**

# Simulations for the nEDM@PSI project - The MCUCN and STARucn codes

## Abstract content

The MCUCN and STARucn codes for tracking ultracold neutron trajectories and spin were developed and further-developed, respectively, within our collaboration in order to perform optimization studies for UCN optics and simulations for the nEDM experiment systematics. In this presentation we will briefly explain capabilities, algorithms, present inter-comparison calculations and analytic benchmarks performed with both codes. Further we will focus on some applications for the nEDM experiment, on (i) calculations of the gravitational depolarization effect on the shape of the R-curves, and (ii) simulations of UCN spin echo for testing the analysis method, aiming for a better field homogenization in the nEDM experiment.

**Primary author(s) :** Dr. ZSIGMOND, Geza (Paul Scherrer Institut)

**Presenter(s) :** Dr. ZSIGMOND, Geza (Paul Scherrer Institut)

**Comments:**

On behalf of the nEDM@PSI collaboration

Abstract ID : **69**

# Studies of perturbations of Larmor precession

## Abstract content

Perturbations of Larmor precession lead to many important effects in physics. In the case of the search for a particle electric dipole moment perturbations due to the combined effects of electric and inhomogeneous magnetic fields lead to a 'false edm' signal which is the major problem in current searches. In the course of studying this effect we have discovered that the distribution of phase angles produced by stochasticaly fluctuating fields is not gaussian, but but satisfies what is known as a Tsallis distribution. We offer an explanation of this effect based on a new treatment of the spin dynamics. Recently we have been able to include realistic velocity changing collisions in our general treatment of the spin dynamics. The results are valid for all values of the mean free path (ballistic to diffusive motion) and can be applied to arbitrary field variations. We show a comparison of the new results with those of the old method where the velocity was taken as constant and the single velocity results were averaged over a Maxwell distribution.

**Primary author(s) :** Prof. GOLUB, Robert (NCSU)

**Presenter(s) :** Prof. GOLUB, Robert (NCSU)

Abstract ID : **46**

# Magnetometry for next generation neutron EDM experiments

## Abstract content

Experiments searching for the electric dipole moment of the neutron require a stable and homogeneous main magnetic field. Statistical and systematic errors in such experiments depend on magnetic field gradients and fluctuations of those gradients and the field itself. We developed a special magnetometer system based on optically pumped Cs vapor that can measure the magnetic field direction in addition to the field's modulus [1, 2]. Spatially resolved vector information about the magnetic field helps to minimize the additional errors caused by temporal and spatial instabilities and thus enables higher nEDM sensitivity. In a different study the absolute accuracy of such magnetometers was investigated [3]. For the next generation neutron EDM experiment at PSI we plan to combine the results of [1] and [3] and realize a vector magnetometer array similar to arrays previously designed for bio-magnetometry [4, 5].

[1] S. Afach, G. Ban, G. Bison, et al. Highly stable atomic vector magnetometer based on free spin precession. Opt. Exp. 23 (17):22108–15, 2015.
[2] S. Afach. Development of a cesium vector magnetometer for the neutron EDM experiment. Ph.D. thesis Nr. 22373, ETH-Zürich, 2014.
[3] Z. D. Grujic, P. A. Koss, G. Bison, and A. Weis. A sensitive and accurate atomic magnetometer based on free spin precession. Eur. Phys. J. D, 69(5), 2015.
[4] G. Lembke, S. N. Erné, H. Nowak, B. Menhorn, A. Pasquarelli, and G. Bison. Optical multichannel room temperature magnetic field imaging system for clinical application. Biomed. Opt. Express, 5(3):62–65, 2014.
[5] G. Bison, N. Castagna, A. Hofer, P. Knowles, J.-L. Schenker, M. Kasprzak, H. Saudan, and A. Weis. A room temperature 19-channel magnetic field mapping device for cardiac signals. Appl. Phys. Lett. 95(17): 173701, 2009.

**Primary author(s) :** Dr. BISON, Georg (Paul Scherrer Institut)

**Presenter(s) :** Dr. BISON, Georg (Paul Scherrer Institut)

Abstract ID : **36**

# High sensitivity Cs sensors for magnetic field measurements in the nEDM experiment

## Abstract content

Measurements of the magnetic field are an inevitable part of experiments searching for an electric dipole moment of the neutron (nEDM). In the nEDM experiment located at the Paul Scherrer Institute (Villigen, Switzerland) there are multiple systems of magnetometers devoted to this task. In this contribution we present a unique approach to magnetic field measurements using a laser operated array of high sensitivity Cs magnetometers. The operation principle of a single sensor is based on optical detection of magnetic resonance of Cs atom. A compact magnetometer design enables operation under vacuum with part of the sensors assembled on the high-voltage electrode. Sixteen Cs sensors are distributed at the top and bottom of the neutron precession chamber and operate continuously during data taking. Constant monitoring of the magnetic field and its gradients assures stable conditions for the nEDM measurements. We describe the components of the Cs array, illustrate its performance and discuss the results of magnetic field measurements. The accuracy of magnetic field readout and future plans are addressed.

**Primary author(s) :** Dr. KASPRZAK, Malgorzata (University of Leuven)

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**Comments:**

for the nEDM collaboration

Abstract ID : **18**

# A Potassium magnetometry based current source for n2EDM

## Abstract content

The nEDM experiment currently taking data at PSI (Paul Scherrer Institut) is in its first phase which should result in a new limit within the next two years. A follow up of the current setup is planned and called n2EDM. This setup will have much improved capabilities in terms of magnetic field monitoring and stability.
The monitoring is typically done via Cesium magnetometers in the experimental volume which monitor the stability and the evolution of the magnetic field. The main field B0 is produced by a dedicated current source. Thus the stability of B0 is fundamentally limited by the stability of the current source.
We plan to build a new ultra-stable current source for our experiment. The idea is to use a commercial very low noise current source and to stabilize its output via a feedback loop. This feedback loop will be installed outside of the nEDM experimental volume. A dedicated coil will be placed in series to the main coil (producing B0). There Potassium magnetometers will monitor drifts in current through drifts in the magnetic field. The feedback loop will correct for such drifts thus stabilizing the output current.

**Primary author(s) :** Mr. KOSS, Peter (KU Leuven)

Abstract ID : **72**

# Precise measurements and shimming of magnetic field gradients in the low field regime

## Abstract content

For many experiments at the precision frontier of fundamental physics, the accurate measurement and knowledge of magnetic field gradients in particular in the low field regime (< microT) is a necessity: On the one hand, in the search for an Electric Dipole Moment (EDM) of free neutrons or atoms, field gradients contribute to geometric-phase-induced false EDM signals for particles in traps. On the other hand, clock comparison experiments like the 3He/129Xe spin clock experiment suffer from gradients, since the coherent T2 * -time of free spin precession, and thus the measurement sensitivity, scales ~1/(grad B)$^2$. Here we report on a new and very effective method, to shim and to measure tiny magnetic field gradients in the range of pT/cm by using effective T2* measurement sequences in varying the currents of trim coils of known geometry.

**Primary author(s) :** ALLMENDINGER, Fabian (University of Heidelberg)

**Presenter(s) :** ALLMENDINGER, Fabian (University of Heidelberg)

# T U E S D A Y

Abstract ID : **52**

# Cosmological constraints on the neutron lifetime

## Abstract content

We derive new constraints on the neutron lifetime based on the recent Planck 2015 observations of temperature and polarization anisotropies of the CMB. Under the assumption of standard Big Bang Nucleosynthesis, we show that Planck data constrains the neutron lifetime to tau_n=(907 +- 69) s at 68 % c.l.. Moreover, by including the direct measurements of primordial Helium abundance of Aver et al. (2015) and Izotov et al. (2014), we show that cosmological data provide the stringent constraints tau_n=(875 +- 19) s and tau_n=(921 +- 11) s respectively. The latter appears to be in tension with neutron lifetime value quoted by the Particle Data Group (tau_n=(880.3 +- 1.1) s). Future CMB surveys as COrE+, in combination with a weak lensing survey as EUCLID, could constrain the neutron lifetime up to a ˜6 s precision.

**Primary author(s) :** SALVATI, Laura (University of Rome, Sapienza)

**Presenter(s) :** SALVATI, Laura (University of Rome, Sapienza)

Abstract ID : **24**

# Review of neutron life time experiments

## Abstract content

Experimental data for neutron life time since the beginning of 70-s from the beam experiments and from the experiments with ultracold neutrons (UCN) are presented in the review. Accuracy of measurements during this time was increased about one order of magnitude. In the middle of 2000-s there was a contradiction between some UCN storage experiments. It was eliminated at the beginning of the 2010-s. Average value of neutron life time from UCN storage experiments 880.0 ±0.9 s was obtained. However, in 2013 the beam experiment was refined and the result 887.7±1.2±1.9 s was presented. The difference in neutron life time values from the beam experiments and UCN storage experiments exceeds 3 standard deviations which demands increase of accuracy of both experiments. In conclusion preliminary measurements of neutron life time in new experiment "Gravitrap 2" with a big gravitational trap will be discussed.

**Primary author(s) :** Prof. SEREBROV, Anatoly (PNPI)

**Presenter(s) :** Prof. SEREBROV, Anatoly (PNPI)

Abstract ID : **56**

# UCNtau: A precision neutron lifetime measurement using a magneto-gravitational trap

## Abstract content

In the UCNtau experiment, we trap ultracold neutrons (UCN) in a magnetic-gravitational trap. The trap, which confines neutrons using magnetic fields and gravity, eliminates neutron loss upon interaction with material surfaces. The apparatus, installed at the Los Alamos UCN source since 2013, has been used to develop and further refine techniques for neutron detection, with an aim to reducing the lifetime uncertainty to 1 s—and below. I will report our first competitive results, with discussions on effects that demonstrate the phase-space evolution.

**Primary author(s) :** Prof. LIU, Chen-yu (Indiana University)

**Presenter(s) :** Prof. LIU, Chen-yu (Indiana University)

**Comments:**

for the UCNtau collaboration.

Abstract ID : **58**

# Status of neutron lifetime experiment UCN magneto-gravitational trap made of permanent magnets.

## Abstract content

The present world average value of the neutron lifetime as quoted by the Particle Data Group, tn = (880.3±1.1) s is dominated by results obtained using ultra-cold neutrons in material bottles. These results, and in particular the most precise of them, appear to be systematically lower than results obtained using a neutron beam and counting trapped protons following neutron decay. New alternative measuring techniques are then called for. The large discrepancy between the results indicates that all systematic effects are not fully under control. The importance of the neutron lifetime in particle physics and cosmology calls for alternative measuring techniques, with high sensitivity but other potential sources of systematic effects. We report measurement of the neutron lifetime using ultra-cold neutrons stored in a magneto-gravitational trap made of permanent magnets. Neutrons surviving in the trap after fixed storage times have been counted and the trap losses have continuously been monitored during storage by detecting neutrons leaking from the trap. The value of the neutron lifetime resulting from this measurement is tn = (878.3±1.9) s. It is the most precise measurement of the neutron lifetime obtained with magnetically stored neutrons. A trap of larger volume is presently being designed to improve the statistical precision.

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**Presenter(s) :** Dr. EZHOV, Victor (Petersberg Nuclear Physics Institute NRC KI)

Abstract ID : **13**

# The neutron lifetime experiment tSPECT

## Abstract content

The decay of the free neutron into a proton, electron and antineutrino is the prototype of semi-leptonic weak decays and plays a key role in particle physics and astrophysics. The most precise measurements of the neutron lifetime to date use ultra-cold neutrons (UCN) stored in material vessels. Their accuracy is limited by systematic errors, mainly caused by anomalous losses of UCN during storage at the vessel walls. With the magnetic storage of neutrons these systematic limitations can be avoided and an accuracy of 0.1-0.3 s for the lifetime of the neutron can be reached. In Mainz the neutron lifetime experiment tSPECT has been set up, which uses a combination of magnetic multipole fields for radial storage and the superconducting aSPECT magnet for longitudinal storage of UCN. In a first phase the goal is to measure the neutron lifetime with a precision of ˜1 s. In this presentation, the status of tSPECT and the results of first commissioning measurements will be presented.

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**Presenter(s) :** Dr. BECK, Marcus (Institut für Physik und Helmholtz-Institut Mainz, Uni Mainz)

Abstract ID : **21**

# The neutron lifetime experiment PENeLOPE

## Abstract content

The experiment PENeLOPE, currently under construction at Technische Universität München, is aiming to measure the neutron lifetime $\tau_{\mathrm{n}} = 880.3 \pm 1.1$ s with high precision. It will store ultra-cold neutrons in a magnetic trap using a large superconducting magnet and will measure their lifetime by both neutron counting and online proton detection. This novel approach should allow an unprecedented precision of 0.1 s.
This presentation will give an overview over the latest developments, especially in magnet design construction and tests, as well as the ultra-cold neutron polarization system.

The project is supported by the Maier-Leibnitz-Laboratorium (Garching), Deutsche Forschungsgemeinschaft and the Excellence Cluster "Origin and Structure of the Universe".

**Primary author(s) :** Mr. SCHREYER, Wolfgang (Technische Universität München, Physik-Department E18)

**Presenter(s) :** Mr. SCHREYER, Wolfgang (Technische Universität München, Physik-Department E18)

Abstract ID : **15**

# Self-Triggering Readout System for the Neutron Lifetime Experiment PENeLOPE

## Abstract content

PENeLOPE is a neutron lifetime measurement at the Forschungsreaktor München II aiming to improve precision of the measurement by one order of magnitude. The experiment employs state-of-the-art readout electronics and a high performance data acquisition system. It features a continuous noise measurement and pedestal tracking, programmable threshold, high voltage control, cryogenic environment and the novel Switched Enabeling Protocol (SEP). The SEP is a transport level layer protocol providing access to muplitple slaves connected to a star-topology optical network using a passive optical splitter. The slaves share the bandwith of the link in a time-division multiplexing manner. The project is supported by the Maier-Leibnitz-Laboratorium (Garching), the Deutsche Forschungsgemeinschaft and the Excellence Cluster "Origin and Structure of the Universe".

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Abstract ID : **32**

# Measurement of neutron lifetime with pulsed cold neutron beams at J-PARC : Experimental apparatus and method

## Abstract content

Neutron lifetime is an important parameter to investigate the unitarity of the CKM-matrix and BBN. Although the neutron lifetime was measured with two methods, which were proton-counting method and neutron-counting method, the significant deviation exists between the reported values. The measurement with different method is quite important to inspect the neutron lifetime. We are proceeding with electron-counting method at J-PARC, Japan. The electron from neutron beta decay is detected by using time projection chamber (TPC). Small amount of $^3$He gas is enclosed in TPC, and $^3$He(n, p)$^3$H reactions are counted to measure the incoming neutron flux in the same volume of the detector. Low-radioactive material, polyether ether ketone (PEEK), is used for main component of the TPC. In the upstream of beamline, the polarization of neutrons are controlled by spin flip chopper (SFC) and neutrons are formed into bunches which are smaller than the TPC volume. The true events are discriminated from background events by using time-of-flight method. The signal to noise ratio of about 1 has been achieved by applying these apparatuses to the intense pulsed neutrons provided by J-PARC. It gives different systematic uncertainties from previous experiments. I will present overview of our experiment.

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**Presenter(s) :** Ms. IEKI, Sei (Department of Physics, Graduate School of Science, The University of Tokyo); SUMI, Naoyuki (Department of Physics, Graduate School of Science, Kyushu University)

Abstract ID : **34**

# Measurement of neutron lifetime with pulsed cold neutron beams at J-PARC : Analysis and Result

## Abstract content

A new experiment for the neutron lifetime has been carried out at J-PARC (Japan Proton Accelerator Research Complex). We acquired the first data in 2014 and 2015, which corresponded to a statistical uncertainty of a few tens of seconds on the neutron lifetime. On our experiment, the neutron lifetime was obtained from a simultaneous measurement of electrons from the beta decay and $^3$He neutron capture reactions recorded by a Time Projection Chamber (TPC). A use of low-acticity materials for the TPC achieved low background environment against each signal. The remaining background events were successfully evaluated by using data-driven methods and Monte Carlo simulations. We concluded that an overall systematic uncertainty became comparable to the statistical uncertainty, i.e., a few tens of seconds. We will report the first result of this experiment and discuss our future plan.

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**Presenter(s) :** Mr. SUMI, Naoyuki (Kyushu University)

Abstract ID : **41**

# Leptoquarks and other new flavor violating currents in the lifetime and beta decay spectrum of ultracold neutrons.

## Abstract content

Ultracold neutrons are constantly proving their merits as an experimental testbed for high energy physics, despite being only a thousandth of a degree above absolute zero. In the southwestern desert of the United States, high precision experiments at the Los Alamos Neutron Science Center (LANSCE) can probe regions of the Standard Model normally associated with LHC physics. The Fierz interference channel, for example, may compete with Standard Model electroweak quark decay from, as yet, undiscovered tensor and scalar interactions in the TeV domain. Fierz interference can influence all three of the decay parameters being measured at LANSCE: the neutron lifetime $\tau_n$, the beta asymmetry coefficient $A$, and the spectral shape parameter $b_n$, also known as the Fierz interference term for the free neutron. I will discuss both the possible new physics that can create a non zero term, and present results and outlook from the UCNA experiment, particularly designed to measure $A$, but capable of setting interesting limits on $b_n$ as well.

**Primary author(s) :** Dr. HICKERSON, Kevin (California Institute of Technology)

**Presenter(s) :** Dr. HICKERSON, Kevin (California Institute of Technology)

Abstract ID : **64**

# Neutron conversion and cascaded cooling in paramagnetic systems for a high-flux source of very cold neutrons

## Abstract content

This talk will present a proposed new neutron-cooling mechanism with a perspective to drastically improve intensities of neutrons with wavelength larger than 2 nm, covering the whole energy range down to ultra cold neutrons. It employs inelastic magnetic scattering in weakly absorbing, cold paramagnetic systems. Kinetic energy is removed from the neutron stepwise in constant decrements determined by electronic Zeeman energy or by zero-field level splitting in magnetic molecules. Molecular oxygen with its triplet ground state appears particularly promising, notably when densely packed as a host in fully deuterated O2-clathrate hydrate. This material possesses an experimentally established non-dispersive inelastic neutron scattering signal with 0.4 meV energy transfer due to the zero-field splitting. Based on calculated cross sections for magnetic neutron scattering and a stationary neutron transport equation for an infinite, homogeneous medium with Maxwellian neutron sources, strong cooling effects are to be expected, requiring only ordinary liquid-helium temperatures, no external magnetic field and no neutron polarisation.

**Primary author(s) :** Dr. ZIMMER, Oliver (ILL)

**Presenter(s) :** Dr. ZIMMER, Oliver (ILL)

Abstract ID : **35**

# The experimental density of states and UCN loss coefficients of fluoropolymers at low temperatures.

## Abstract content

We report the inelastic neutron scattering (INS) measurements of the density of vibrational states $G(\omega)$ of four fluoropolymers which differ by chemical composition, molecular weight and solidification temperatures. These polymers are promising for the storage of ultra cold neutrons in closed volumes covered with polymer film. From inferred $G(\omega)$ we calculate the expected UCN loss coefficients and compare them with the existing experimental data.

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**Presenter(s) :** Dr. POKOTILOVSKI, Yuri (Joint Institute for Nuclear Research)

Abstract ID : **65**

# Investigation of perfluorinated methylene oxide oligomers (PFMO) for UCN storage

## Abstract content

The free neutron lifetime τn plays an important role in fundamental physics. One example is the primordial mass fraction of 4He Yp, the ratio of helium over hydrogen in the early Universe, which depends on the neutron lifetime [1]. The uncertainty of the value of the neutron lifetime was recently raised from 0.8 seconds to 1.1 seconds due to three new wall storage experiments whose results were taken into account [2]. To support solving this "Puzzle of Neutron Lifetime", we have been preparing an UCN storage experiment with a novel wall coating since 2012. We were able to obtain and analyze a perfluorinated polymer (IUPAC Name: Bis(per- fluorobutoxy)difluormethan; used abbr. PFMO) as proposed by Pokotilovski in 2002 [3]. It fulfills both specifications a hydrogen free wall material and a very low melting point (-152°C). At this low temperature losses due to inelastic scattering of neutrons can be further reduced [4].

In 2015 we have performed a storage experiment at ILL, Grenoble, which provides all features to measure the neutron lifetime. It is based on a copper storage bottle which can be cooled sufficiently and stable down to -195 °C. The wall material for the storage at this beam time was the polymer mentioned above. It was sprayed onto the cooled inner walls and tempered in advance of the storage measurements. The frequency of wall collisions was reduced by changing the cut-off energy of the UCN by a neutron absorber. While the entire mechanics and electronics of the experimental setup were tested successfully, the proposed properties of this polymer could not be proven yet. At the moment investigations of the reasons that led to the lower than expected storage time are carried out. Nevertheless, a repetition of the experiment with a similar polymer in addition whose characteristics are already well known is indicated. The experimental setup of this UCN storage experiment and its usability for testing various polymers as wall materials will be presented.

The project was funded by the Cluster of Excellence PRISMA and the Friedrich Naumann-Stiftung für die Freiheit.

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**Co-author(s) :** Prof. REICH, Tobias (Johannes Gutenberg University Mainz); Mr. POKOTILOVSKI, Yuri (, Joint Institute for Nuclear Research, Dubna, Russia)

Abstract ID : **47**

# Advanced UCN Hardware for future experiments with ultracold neutrons

## Abstract content

Ultracold neutrons (UCN), neutrons with energies on the neV scale are unique probes for testing our actual understanding of particle physics and the universe. Playing a leading role in the worldwide UCN business in future, important projects, e.g. the development of a powerful UCN source and the installation of flagship experiments like the nEDM and n-lifetime have been started at the FRMII in collaboration with the universe cluster and the department of physics some time ago. In order to obtain highest performance within these projects, dedicated neutron optical devices for the UCN transport, storage, polarization and detection are mandatory. Based on our technical know how in the field of advanced UCN hardware, the Movatec GmbH was founded in Eching (Bavaria) in January 2016. This talk will give an overview on existing infrastructure, current and past developments and future posibilities for interested Partners.

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**Co-author(s) :** Mr. ZECHLAU, Thorsten (Movatec GmbH)

**Presenter(s) :** Dr. LAUER, Thorsten (Movatec GmbH)

Abstract ID : **66**

# Development of high position resolution neutron detector using fine-grained nuclear emulsion

## Abstract content

We started the development of high position resolution neutron detector using fine grained nuclear emulsion and nuclides which emit ionizing particles after capturing neutrons. Since 2010, we started the production of nuclear emulsion gel at our laboratory in Nagoya University. Fine-grained nuclear emulsion consists of AgBr crystals with their diameter of 40nm is developed. We added LiNO3 into the fine-grained emulsion gel. 6Li emits an alpha particle and a tritium after capturing a neutron. An alpha particle makes a track with its length of 7 microns and tritium, 40 microns. We exposed the emulsion with LiNO3 to neutrons with kinetic energy of about 10 meV at KUR and J-PARC and detected capture events of them. From grain densities or ranges of tracks of alpha particles and tritiums, accuracy in deciding the capture points is about 0.5 micron.

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**Presenter(s) :** NAGANAWA, Naotaka (Nagoya University Physics Department)

# W E D N E S D A Y

Abstract ID : **60**

# qBOUNCE – Realization of a Quantum Bouncing Ball Gravity Spectrometer

## Abstract content

This talk focuses on the control and understanding of a gravitationally interacting elementary quantum system using the techniques of resonance spectroscopy. It offers a new way of looking at gravitation at short distances based on quantum interference. The ultra-cold neutron reflects from a mirror in well-defined quantum states in the gravity potential of the earth allowing the application of gravity resonance spectroscopy (GRS). GRS relies on frequency measurements, which provide a spectacular sensitivity. The neutron gives access to all parameters: distance, mass, curvature, energy-momentum tensor, and torsion. We present limits on dark energy and dark matter candidates [Jen14].
[Jen14] T. Jenke et al., Phys. Rev. Lett. 112, 151105 (2014).

**Primary author(s) :** Prof. ABELE, Hartmut (TU Wien)

**Presenter(s) :** Prof. ABELE, Hartmut (TU Wien)

Abstract ID : **55**

# Neutrons as a window to parallel world

## Abstract content

I shall discuss the neutron oscillation phenomenon into mirror neutron, a mass degenerate twin from hypothetical dark parallel sector, and its phenomenological and astrophysical consequences

**Primary author(s) :** Prof. BEREZHIANI, Zurab (University of L'Aquila)

**Presenter(s) :** Prof. BEREZHIANI, Zurab (University of L'Aquila)

Abstract ID : **59**

# Neutron-mirror neutron regeneration experiment

## Abstract content

We will discuss an idea of a new small experiment with the cold neutron beam proposed for the Spallation Neutron Source SNS at ORNL. The controversial indications seen in the previous mirror neutron disappearance search experiments with UCN traps can be unambiguously tested here by re-appearance (regeneration) method. Oscillating neutron beam will be completely absorbed by the beam stop such that only mirror neutrons will be able to pass through the absorbing wall and then reappear back by oscillations as neutrons. Limits of detection and exclusion of the effect will be discussed.

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**Presenter(s) :** Prof. BEREZHIANI, Zurab (Univ. L'Aquila)

Abstract ID : **23**

# Experiment on search for neutron–antineutron oscillations using a projected UCN source at the WWR-M reactor

## Abstract content

An experiment on search for neutron–antineutron oscillations is proposed based on the storage of ultracold neutrons (UCNs) in a material trap. The main factors influencing sensitivity of the experiment are the trap size and the amount of UCNs trapped. A high-intensity UCN source will be created at the WWR-M reactor of Petersburg Nuclear Physics Institute, which must provide an UCN density two to three orders of magnitude higher than that in the existing sources. The results of simulations of the experiment for detecting neutron–antineutron oscillations with the new source show that the sensitivity can be increased by ~ 20–80 times compared to existing sensitivity. The range depends on the model of neutron reflection from walls.

**Primary author(s) :** Prof. SEREBROV, Anatoly (PNPI); Dr. FOMIN, Alexey (PNPI); Prof. KAMYSHKOV, Yuri (University of Tennessee)

**Presenter(s) :** Dr. FOMIN, Alexey (PNPI)

Abstract ID : **26**

# Tests of the Weak Equivalence Principle with UCNs

## Abstract content

The equivalence of the gravitational and inertial masses is one of the most fundamental physical principles. The present-day approach to its testing is based on the employing of different test bodies whose important properties, such as the binding energy per unit mass, atomic mass, and ratio of the number of neutrons to the number of protons, differ as much as possible. From this point of view, investigation of the gravitational interaction of a free neutron is of particular interest. Several years ago we performed a neutron gravity quantum experiment of a new type [1]. The gain in kinetic energy of free-falling neutrons was compensated by a quantum of energy $\hbar\Omega$, due to phase modulation of the neutron wave. As a phase modulator, a grating moving perpendicular with respect to the direction of the neutron wave propagation was used. As a result, monochromatic neutrons had exactly the same energy after falling as before the freefall. The weak equivalence principle was tested to an accuracy of $2 \times 10^{-3}$. Later it was proposed to modify the experimental approach to increase the precision of such an experiment [2]. For realization of this idea a new gravitational UCN spectrometer was built. In this installation the periodical modulation of the neutron flux was used for the UCN spectroscopy in addition to Fabry–Pérot interferometers (neutron interference filters). As before, a rotating grating was used as a phase modulator for the splitting of the initial spectrum. The statistical error of $\Delta g/g$ obtained with this spectrometer, was $10^{-3}$ per day [3]. At the same time certain systematic problems were found. The most important of them was the contradiction between the calculated and the expected spectra of UCN diffracted by a moving grating. It is necessary to stress that the used technique of UCN spectrometry permitted us to observe only the lines of plus/minus first diffraction orders. Recently this situation has changed significantly. First, certain progress was made in the theory of the phenomenon [4]. Besides it was realized that, using the Fourier TOF method, it is possible to measure relatively wide-range UCN spectra. It has been demonstrated experimentally [5] that this technique permits one to investigate the position, intensity and width of the diffraction lines up to at least plus/minus second or even third diffraction orders. These results have led us to the idea to perform free-fall experiments, based on the simultaneous measuring of the time-of-flight neutrons from different lines of the spectrum formed by neutron diffraction from a moving phase grating [6]. The advantage of this approach is that neither the initial neutron energy, nor the geometry parameters of the installation are required to be known in this method.

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Abstract ID : **43**

# The neutron charge experiment in Mainz

## Abstract content

We aim to investigate the charge of the free neutron by means of an optical system with an accuracy of about 10^-22 e. For this, the deflection of an optical image with neutrons in an electric field is determined. We will present the current status of our charge experiment for ultracold neutrons. First measurements were carried out in November 2014 at the ILL. In this run, a statistical sensitivity of 2.4*10^-20 e/sqrt (d) was achieved. Various systematic effects were determined thoroughly. The results of this beam time are of great importance for the further development of this experiment.

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**Presenter(s) :** Dr. SIEMENSEN, Christian (Institut für Kernchemie)

Abstract ID : **33**

# Diffraction of UCN by a moving grating and TOF Fourier spectrometry as the basis for gravity experiments

## Abstract content

Our latest experiments on testing the equivalence principle for neutrons have been based on the combined use of a moving diffraction grating and Fabry-Pérot interferometers [1]. Recently, it has been recognized that the use of the moving diffraction grating in combination with the time-of-flight Fourier spectrometry opens a new possibility for the experiment to test the weak equivalence principle for the neutron [2].
The report presents the first experience of using a time-of-flight Fourier spectrometry technique for measurement of the energy spectra from the diffraction of monochromatic ultracold neutrons on a moving grating. Lines of 0, $\pm 1$ and $\pm 2$ diffraction orders were simultaneously recorded, which had previously been impossible to be done by other methods. Even these first results have made it possible to make a comparison with the recent theoretical calculations [2] based on the dynamical theory of neutron diffraction on a moving phase grating. In qualitative agreement with the theory we observed a change of the ratios in the line intensity of different diffraction orders with a varying velocity of the grating.
The energy resolution of the instrument was no worse than 4% and the range of the measured energies was from 50 to 150 neV.
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[2] Zakharov M.A., Kulin G.V., Frank A.I., Kustov D.V., Goryunov S.V. arXiv:1602.00941v1.
[3] Bushuev V.A., Frank A.I., Kulin G.V. JETP 122 (2016) 32; arXiv:1502.04751v1.

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**Presenter(s) :** Dr. KULIN, German (Joint Institute for Nuclear Research)

# T H U R S D A Y

Abstract ID : **53**

# Neutron decay correlations in the standard model and beyond

## Abstract content

The present status of neutron decay correlation data is reviewed, and its implications for searches on new physics beyond the standard model are discussed.

**Primary author(s) :** Prof. DUBBERS, Dirk (Heidelberg University)

**Presenter(s) :** Prof. DUBBERS, Dirk (Heidelberg University)

Abstract ID : **39**

# Physics Beyond the Standard Model from Neutron Beta Decay Correlations at LANSCE

## Abstract content

The Los Alamos Neutron Science Center (LANSCE) has developed the leading facility for precision measurements of polarized neutron beta decay observables using ultracold neutrons. The UCNA experiment is the flagship for the facility, which published the result for the beta asymmetry $A_0 = -0.11952(110)$ in 2013 and is currently analyzing its most recent data-taking cycle. The facility is now pursuing a major effort to determine the neutron lifetime to 1 s precision, which, along with the beta-asymmetry, can be used to precisely extract the CKM parameter $V_{ud}$. A new detection system based on large area, thin deadlayer, highly pixellated silicon detectors is being developed for use in the UCNA spectrometer. The UCNB detection system can detect both the proton and electron in coincidence and access additional angular correlations, in particular the antineutrino asymmetry $B$, to gain sensitivity to Beyond Standard Model scalar and tensor current interactions. The UCNB collaboration has completed its first data-taking run using a partially instrumented dual detection system in an asymmetric configuration. An overview of the scientific program at LANSCE will be given, plans for the fully instrumented, symmetric UCNB experiment will be discussed, and prospects for a next-generation UCNA experiment will be presented.

**Primary author(s) :** Dr. BROUSSARD, Leah (Los Alamos National Laboratory)

**Presenter(s) :** Dr. BROUSSARD, Leah (Los Alamos National Laboratory)

Abstract ID : **54**

# Probing non-standard charged-current interactions: from UCN to the LHC

## Abstract content

The Effective Field Theory approach is a useful framework to analyze and compare different New Physics searches. I will discuss its application to nuclear/neutron beta decay, and LHC processes. The various relevant hadronic form factors will be also discussed with some detail.

**Primary author(s) :** GONZALEZ-ALONSO, Martin (IPN Lyon)

**Presenter(s) :** GONZALEZ-ALONSO, Martin (IPN Lyon)

Abstract ID : **51**

# The Proton Electron Radiation Channel Experiment (PERC)

## Abstract content

Neutron beta decay is an excellent system to study the charged weak interaction experimentally. The decay is precisely described by theory and unencumbered by nuclear structure effects. Observables are numerous correlation coefficients, spectra and the neutron lifetime. Most importantly, precision measurements in neutron beta decay are used to investigate the structure of the weak interaction and to derive the CKM matrix element Vud.
In this talk, I will focus on the new instrument PERC, which is currently under construction at the FRM II, Garching by the PERC collaboration. It's main component is a 12 m long superconducting magnet system. PERC is designed to improve measurements of several correlation coefficients by an order of magnitude. I will present the concept of the instrument as well as its current status.

**Primary author(s) :** Prof. MÄRKISCH, Bastian (Technische Universität München)

Abstract ID : **44**

# The aSPECT experiment - an overview and latest results

## Abstract content

The aSPECT retardation spectrometer measures the β−ν angular correlation coefficient a in free neutron β-decay. This measurement can be used to determine the ratio gA/gV of the weak coupling constants, as well as to search for physics beyond the Standard Model.
In spring/summer 2013 aSPECT had a successful beam time at the Institut Laue-Langevin. The goal of this beam time is to improve the current uncertainty of a from $\Delta$ a/a$\sim$ 5% to about 1%. The data analysis is in its final stage and will be finished soon. In order to achieve an uncertainty of 1%, the systematics of aSPECT have to be understood accordingly. This understanding is obtained from systematic tests and measurements of a with different parameter settings for the spectrometer during the beam time. Additionally, offline measurements have been performed to determine the effect on the systematics, e.g. work-function fluctuations of the electrodes, the magnetic field ratio of the spectrometer and detailed tests of the detector electronics. These measurements are used as input for sophisticated simulations of the spectrometer to understand and reduce the systematic uncertainties further.
In this talk we will present an overview of aSPECT and its measuring principle. The beam time 2013 will be presented in detail, including the current status of the data analysis and preliminary results for systematic effects and their uncertainties.

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**Presenter(s) :** Mr. WUNDERLE, Alexander (Johannes Gutenberg-Universität Mainz)

Abstract ID : **48**

# NoMoS: Beyond the Standard Model Physics in Neutron Decay

## Abstract content

The newly established New Frontiers Group 'NoMoS: Beyond the Standard Model Physics in Neutron Decay' of the Austrian Academy of Sciences aims to search for traces of new physics in neutron beta decay with novel experimental techniques.
Precision measurements in neutron decay allow searching for physics beyond the Standard Model. An accuracy of $10^{-4}$ in the observables corresponds to energy scales of $1 - 100$ TeV for new particles and interactions. To achieve this accuracy, a new technique is developed: R×B spectroscopy. For measurements at ultimate statistics, the R×B spectrometer will be combined with PERC, a new facility at FRM II in Garching/Germany.

**Primary author(s) :** Dr. KONRAD, Gertrud (Stefan Meyer Institute Vienna)

**Presenter(s) :** Dr. KONRAD, Gertrud (Stefan Meyer Institute Vienna)

Abstract ID : **20**

# Impact of the transverse electron polarization related neutron beta decay correlations in the LHC era

## Abstract content

Neutron beta decay correlation coefficients are linearly sensitive to the exotic scalar and tensor interactions that are not included in the Standard Model. This nice feature can be, however, significantly suppressed or even completely destroyed since experiments deliver these coefficients divided by the expession containing the Fierz interference term $b$. Fortunatelly, the transverse electron polarization related coefficients $H$, $L$, $N$, $R$, $S$, $U$ and $V$ are safe with that respect. The proposed experiment will measure simultaneously 11 neutron correlation coefficients (additionally $a$, $A$, $B$ and $D$) where 5 of them ($H$, $L$, $S$, $U$, $V$) were never addressed before. Silicon pixel detectors are considered as promising alternative to multi-wire gas chambers devoted for electron tracking in the original setup. The expected sensitivity limits for $\epsilon_S$ and $\epsilon_T$ – EFT parameters describing the scalar and tensor contributions to be extracted from the transverse electron polarization related coefficients $H$, $L$, $N$, $R$, $S$, $U$, $V$ will be discussed. The proposed approach is complementary to other projects aiming at the extraction of exotic couplings from beta spectrum shape measurements or from beta-neutrino correlations.

**Primary author(s) :** Prof. BODEK, Kazimierz (Institute of Physics, Jagiellonian University in Krakow)

**Presenter(s) :** Prof. BODEK, Kazimierz (Institute of Physics, Jagiellonian University in Krakow)

Abstract ID : **50**

# A Cold Neutron Beam Facility for Particle Physics at the ESS

## Abstract content

Pulsed beams have tremendous advantages for precision experiments with cold neutrons. In order to minimise and measure systematic effects, they are used at continuous sources in spite of the related substantial decrease in intensity. At the pulsed neutron source ESS, such experiments will gain up to a factor of 30 in event rate, and novel concepts become feasible. Therefore, the cold neutron beam facility for particle physics ANNI was proposed as part of the ESS instrument suite. Scientific case, concept and expected performances of ANNI will be presented.

**Primary author(s) :** Prof. MÄRKISCH, Bastian (Technische Universität München)

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**Presenter(s) :** Prof. MÄRKISCH, Bastian (Technische Universität München)

Abstract ID : **68**

# A Brief Overview of Ultracold Neutron Source Development and Some Points of Personal Interest

## Abstract content

We present a brief overview of some of the properties and principles of operation of the Ultracold Neutron (UCN) sources currently in "production mode", as well as sources under development. A few outstanding issues and challenges are identified in optimizing UCN fluxes provided to experiments. Finally, for some specific cases, we present ideas to increase available UCN densities and/or currents beyond what is currently available or planned at facilities under construction.

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Abstract ID : **22**

# The ultracold and very cold neutron facility PF2 at the Institut Laue Langevin in Grenoble, France

## Abstract content

The ultracold neutron (UCN) and very cold neutron (VCN) facility PF2 (Physique Fondamentale 2) is one of two public installations at the Institut Laue Langevin (ILL) where fundamental properties of the free neutron can be studied. It came into operation in 1985 (TU Munich in collaboration with the ILL) and is ILL's only user instrument located on level D of the reactor building. Its close distance to the reactor core necessitates important safety measures, especially after the Fukushima event. After 30 years of successful and reliable operation, PF2 is still the strongest UCN user source in the world, providing densities of up to 30 UCNs per cm3 with speeds less than 8 ms-1 at the different experimental positions. It also provides a unique beam of VCNs peaking around 10 nm. PF2 is a "high current DC source" with a constant flux and able to fill any experimental volume without load on the source. It offers four UCN beam positions, three in time sharing mode, and one VCN beam position to the users. While the user groups bring their dedicated equipment to the corresponding beam positions, the PF2 crew adapts it to the beam position, also ensuring smooth operation of the groups operating experiments in parallel at the various beam ports of PF2.

The UCN facility PF2 is based on neutron moderation in liquid deuterium located near the maximum of primary thermal flux of the reactor, followed by extraction of very cold neutrons through a vertical guide and a phase space transformation using a neutron turbine. A. Steyerl (TU Munich) pioneered the neutron turbine which he proposed already in 1966 while P. Ageron (ILL) suggested in 1978 to feed such a turbine using a dedicated vertical guide dipping into ILL's vertical cold neutron source. The advantage of extracting VCNs from the cold source is that they are much less sensitive to losses in the unavoidable safety windows in the beam line than UCNs. In addition, they undergo much fewer reflections in the guides, which minimizes transport losses from the primary source to the turbine where the VCN are finally decelerated into the UCN regime close to the different experimental positions.

The strength of PF2 is its availability, reliability and adaptability: once the reactor is on and the cold sources are running, UCNs/VCNs are available at all experimental positions 24 hours a day for the full reactor cycle. Each user group can work independently of others working at different beam positions and has access to its position round the clock.

The principle of this source will be described in detail and the ongoing and near future research programme will be outlined.

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Abstract ID : **16**

# The ultracold neutron facility at the Paul Scherrer Institute

## Abstract content

At the Paul Scherrer Institute (PSI) in Switzerland a new generation ultracold neutron (UCN) facility has been in regular operation since 2011. A 590 MeV, 2.2 mA proton beam impinging for up to 8 s every few hundred seconds on a lead target produces via spallation about 7 neutrons per initial proton. These are subsequently moderated in heavy water. The following cold moderation and production of UCN is done in 5 kg of solid deuterium at 5 K. The UCN are transported over ˜9m to three beam ports. The UCN source facility provides high UCN intensities to experiments, with the search for an electric dipole moment of the neutron installed at one beam port.

An overview of the experience with operating the source and the present status and performance of the facility will be given. We will discuss our strategy to fully understand all steps leading to the UCN delivery: proton beam, neutron production and moderation, UCN production and UCN transport to the beam ports. Results of various characterization measurements will be shown.

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**Comments:**

" Oral presentation "
on behalf of the PSI UCN Team

Abstract ID : **73**

# Sources for ultracold neutrons: a world-wide comparison

## Abstract content

The ultracold neutron (UCN) density provided to experiments at a UCN source is an important benchmark parameter. In 2015 we have performed UCN density measurements with a 'norm' UCN storage bottle of about 30L volume at all operating UCN sources world-wide, in order to establish a standard procedure and setup for comparable UCN density measurements. The setup and measurement procedure will be explained and preliminary results will be presented.

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Abstract ID : **45**

# Upgrades to the ultracold neutron source at Los Alamos Neutron Science Center

## Abstract content

The spallation-driven solid deutrium-based ultracold neutron (UCN) source at Los Alamos Neutron Science Center (LANSCE) has provided a facility for precision measurements of fundamental symmetries via the decay observables from neutron beta decay for nearly a decade. In preparation for a new room temperature neutron electric dipole moment (nEDM) experiment and to increase the statistical sensitivity of all experiments using the source an effort to upgrade the existing source is planned for 2016. The ultimate goal is to provide a density 100 UCN/cc in the nEDM storage cell 10 m from the source. This upgrade includes a redesign of the cold neutron moderator and UCN converter geometries, improved coupling and coating of the UCN transport system through the biological shielding, optimization of beam timing structure, and increase of the proton beam current. We will present the results of the MCNP and UCN transport simulations that led to the new design, which will be installed spring 2016, and UCN guide tests performed at LANSCE and the Institut Laue-Langevin to study the UCN transport properties of a new nickel-phosphorus guide coating.

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Abstract ID : **62**

# Status of the UCN source at beamport D of the research reactor TRIGA Mainz

## Abstract content

A new superthermal source for ultra-cold neutrons (UCN) based on solid deuterium as converter [1] has been installed at the pulsed reactor TRIGA Mainz . This source delivers up to 240 000 UCN (v $\leq$ 6 m/s) per pulse at the experimental area and is well suited for storage experiments to study fundamental properties of the free neutron like its lifetime. UCN densities of approx. 10/cm3 have been obtained in storage experiments using stainless steel bottles with a volume of approx. 10 L [2]. After the installation of a He liquefier, the UCN source can be used for long-term experiments. The status of this source as well as its planned upgrade will be presented.

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2. Karch, J., Sobolev, Yu., Beck, M. et al.: Performance of the solid deuterium ultra-cold neutron source at the pulsed reactor TRIGA Mainz, Eur. Phys. J. A 50 (2014) 78

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# F R I D A Y

Abstract ID : **74**

# Neutron EDM Measurement with Spallation UCN Source of He-II

## Abstract content

Here we discuss our method of nEDM measurement and UCN production. We produce neutrons by means of spallation reactions. Neutron temperature is moderated down to a cold neutron region in thermal and cold heavy waters. He-II is placed in the cold moderator. UCN are produced upon cold neutron down scatterings in the He-II, and then confined in a storage bottle, which is equipped with a UCN valve. For EDM measurement, the UCN valve is opened. UCN go out from the He-II through a cryogenic window, where a magnetic field is applied for enhancing UCN transmission. The enhancement has spin dependence, therefore, UCN spins are polarized upon the transmission. Polarized UCN are transported into an EDM measurement cell placed in a magnetic field of a spherical coil and an electric field, where UCN spin precession is observed. An EDM effect is found in the precession phase which depends on the electric field. The magnetic field is monitored during the UCN spin precession by means of 129Xe spin precession. In this workshop, we will discuss the present status and future possibilities of our experiment.

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Abstract ID : **31**

# Design and results of cryogenic commissioning tests of the PULSTAR UCN source

## Abstract content

The Ultra-Cold neutron source, build at the PULSTAR reactor on the campus of NC State University, has been in an active cryogenic commissioning phase since the spring of 2015; The source cryostat is designed for 3-step moderation using heavy water, solid methane and solid deuterium to optimize UCN production. At present the cryostat is located outside the reactor bio-shield for cryogenic testing. In the spring-summer of 2015 tests of the methane and deuterium condensation confirmed the design goal of cooling powers and demonstrated the proper working of all instrumentation. Since then we modified the deuterium cryostat to add optical elements for visualization of SD2 growth in-situ as well as temperature sensors immersed into the SD2 bulk to characterize quality of the crystal. We also added a Para/Ortho convertor to our gas handling system. First results of optimization of ortho-SD2 crystallization will be presented.

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**Presenter(s) :** Dr. KOROBKINA, Ekaterina (NC State University)

Abstract ID : **27**

# Ultracold Neutrons at the FRM II

## Abstract content

At the FRM II in Munich a new strong source for ultracold neutrons is currently build up. UCN produced in a solid deuterium converter will be distributed to four experimental areas. In this talk the status of the UCN source at the FRM II will be presented.

**Primary author(s) :** Dr. FREI, Andreas (TU München - FRM II)

**Presenter(s) :** Dr. FREI, Andreas (TU München - FRM II)

Abstract ID : **25**

# UCN source with superfluid helium at WWR-M reactor

## Abstract content

The WWR-M reactor at PNPI is going to be equipped with a high density ultracold neutron source. Method of UCN production is based on their accumulation in the super fluid helium due to particular qualities of that quantum liquid. High density of UCN will be achieved by putting source directly into the thermal column of the WWR-M reactor, where the thermal neutron flux reaches 3.2 e 12 n/cmˆ2s. The cold neutron (9 Angstrom) flux will be dF/dlambda (9 Angstrom)= 3.2e10 n /cmˆ2sAngstrom. Neutron fluxes and heat load in UCN source were calculated by using MCNP program. The main technical problem here is the total heat load (P= 19 W) on superfluid helium. To solve this problem a full-scale model of the UCN source that simulates heat inflows from the reactor has been created and launched. Early experiments showed the possibility of removing 15W heat from 1.3 K superfluid helium. Our source aims at obtaining a density of UCN up to 10000 n/cmˆ3, 100 greater then in existing sources presently available in the world. Increase in the density of UCN will raise the accuracy of the measurement of the neutron electric dipole moment, neutron lifetime etc.

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**Presenter(s) :** Mr. LYAMKIN, Vitaliy (PNPI)

Abstract ID : **29**

# Irradiation effects on Solid Deuterium

## Abstract content

At the Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II) a new source for ultra-cold neutrons is currently under construction. This source is going to use solid deuterium as a converter material. This deuterium will be located close to the reactor fuel element ($\sim 60\,\mathrm{cm}$). During normal reactor operation it will be under irradiation by fast neutrons as well as gamma and beta radiation coming from the surrounding aluminum beam tubes.
Since only the ortho state of deuterium can be used to produce ultra-cold neutrons, it is worthwhile to study the effects of the irradiation on the ortho-/para ratio.
This talk will give an overview of an experiment to study these effects, where a solid deuterium crystal was bombarded with 20.5 MeV protons.

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**Presenter(s) :** Mr. WLOKKA, Stephan (Heinz Maier-Leibnitz Zentrum, Technische Universität München, Lichtenbergstraße 1, 85748 Garching)

Abstract ID : **28**

# A new ultracold neutron source at the TRIGA Mainz

## Abstract content

Ultracold neutrons are a unique tool for the investigation of fundamental properties of the free neutron and its interactions. The successful installation of a new superthermal source for ultracold neutrons based on solid deuterium at the TRIGA Mainz reactor will be described. This source can run either continously with the TRIGA reactor at a power of 100 kW, or with the reactor being operated in pulsed mode. In a first series of measurements this source has been characterized. These experimental results will be presented.

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