The new Ultracold Neutron Source at PSI: status and first results from commissioning

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Overview

- Design concept of the UCN source
- Status of essential components
  - Proton beam
  - Spallation target
  - UCN tank system
  - Heavy water system
  - Deuterium moderation system
  - UCN storage volume
  - Neutron guides
- Summary and Outlook
UCN-Source

- Pulsed 1.3 MW p-beam 600 MeV, 2.2 mA, 1% duty cycle
- Spallation target (Pb/Zr) (~10 neutrons per proton)
- Heavy water moderator, thermal neutrons
- UCN storage volume, height 2.5 m, 2 m³, $\rho_{\text{UCN}} \sim 2000$ cm⁻³
- UCN shutter
- Cold UCN-converter 30 dm³ sD₂ at 5 K, $\rho_{\text{UCN}} \sim 5000$ cm⁻³
- Thermal shield (70K)
- Opening for neutron guide, $\rho_\text{U} \sim 1000$ cm⁻³
- UCN shutter
- Thermal shield (70K)
Commissioning of the proton beam line including the UCN spallation target with full beam, 15.-18.12.2009

- 5ms beam kicks during test
- 80 kicks in total (in 3x2 hours period)

2mA, 5ms pilot beam operation possible with trajectory correction
Pb/Zr Spallation Target

target is inserted
delivery of tank: Sept. 04, 2008

February 2009
D$_2$O system finished:
• system filled with 5m$^3$ D$_2$O (99.93% purity)
• control system commissioned in Nov. '09
• successfully operating during p-beam tests in Dec. '09

the heavy water system is used for moderation of fast neutrons and target cooling
D$_2$O Cooling Plant

heavy water pump (25 l/s)

heat exchanger

D$_2$O drain tanks in cellar
He and D₂ Cryogenic System

Helium-Refrigerator

D₂ buffer tanks
30m³, 1bar

Cryobox
Condensation vessel,
Conversion vessel,
Phase separator,
cryo valves, etc.

Cryogenic Connection Line
1x D₂ line,
2x He-shield,
2x 5K He-supply,
2x 5K He-return

Cryopump
Temp.: ~5K

He-refrigerator cooling power:
370W @ 4.2K and
2500W @ 80K

Thermal Shield
Temp.: ~70K

sD₂ Moderator Vessel
30dm³ sD₂, Temp.: ~5K

sD₂ buffer tanks
30m³, 1bar
sD$_2$-Moderator Vessel

- 0.5 mm AlMg3
- 2 x 1.5 mm AlMg4.5Mn
- 500 mm
- 200 mm
Production of Moderator Vessel

- calotte: 0.5 ± 0.05 mm wall thickness
- milled from one AlMg3 piece
- bottom part (NiMo coated) with central channels for Helium and D₂
- no plastic deformation for inside pressures between -1 ... +3 bar!!
Details of sD2-Moderator Vessel

- all parts EB welded
- cooling channels made by wire erosion

Helium-flow direction
500'000 cycles in vacuum at 77K
D$_2$ Gas management System

valve boxes and D$_2$ gas management system

30 m$^3$ D$_2$ gas buffer
Storage Volume and Shutters

- neutron guide shutter
- > 800,000 cycles at RT and 60 K
- storage volume: 500nm DLC coated
Mounting of Storage Volume

storage volume in mounting rack (7m)

view into storage volume
UCN density profile as function of source filling time – snapshots

$E_{\text{max@bottom}} = 250$ neV, guide shutters closed

(by G. Zsigmond)
Vertical Neutron Guide  
made from ultrapure aluminum

- Inner surface milled on a vibration-damped diamond mill
  roughness: < 50nm
- Inner surface coated with 500 nm NiMo (85/15)
- Reflectometry measurement of inner surface:
  \( V_{\text{Fermi}} = 223 \pm 10 \text{ neV} \)
Test Installation of Storage Volume

- iron shielding
- thermal shield
- vertical neutron guide
- UCN vacuum tank
most UCN guides are made of borosilicate glass, Ø = 18cm, transmission tests successfully carried out at ILL in Grenoble:
98% transmission per meter

NiMo coating: ~ 500 nm roughness: < 1 nm (glass)

length of glass pipe: max. 3.6 m

thermo adaptor made of stainless steel
Measurement of critical reflection angle by means of cold neutrons reflectometry (at the NARZISS instrument at PSI)

<table>
<thead>
<tr>
<th>glass guide</th>
<th>length (mm)</th>
<th>measured $V_{\text{Fermi}}$ (neV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1W-1</td>
<td>3499</td>
<td></td>
</tr>
<tr>
<td>1W-2</td>
<td>2320</td>
<td></td>
</tr>
<tr>
<td>1S-1</td>
<td>3668</td>
<td></td>
</tr>
<tr>
<td>1S-2</td>
<td>2497</td>
<td></td>
</tr>
<tr>
<td>2W-1</td>
<td>1530</td>
<td></td>
</tr>
<tr>
<td>2W-2</td>
<td>2650</td>
<td>220 ± 10</td>
</tr>
</tbody>
</table>

(B. Lauss / PSI)
Prestorage method for UCN transmission measurement

Measurement sequence starts with prestorage to shape UCN energy spectrum then the UCN are sent through the test guide and counted.
Prestorage method for UCN transmission measurement

Setup for UCN flux calibration

UCN from turbine

counter to monitor UCN flux

prestorage volume

1m glass NiMo coated

Ni and Stainless steel flanges

pumping lines

UCN to monitor UCN flux

VAT1

VAT2

VAT3 (open)

Test guide

movable detector
Interpretation:

a) emptying of prestorage volume
   -> 1 exp. slope

b) emptying of prestorage volume + emptying of 360 cm guide volume
   -> 2 exp. slopes

The goal is to separate direct (specular) transmission and scattered (diffuse) transmission.

(B. Lauss, L. Göltl / PSI)
Preliminary results:

Transmission of guides including flanges and slits at connection valves per meter:

\[ T/m = 0.98 \pm 0.02 \]

Comparing different lengths of guides allows to remove the flange and slit contributions:

\[ T/m \text{ of NiMo coating on glass substrate} = 0.99 \pm 0.02 \]

(B. Lauss, L.Göltl / PSI)
Micro UCN detector
for direct UCN monitoring in storage volume

GS10 (\(^6\)Li based)
glass scintillator
\(\phi = 3\) mm
thickness = 0.1 mm

\(\phi = 2\) mm holes for 4 counters

by direct measurement of UCN count rate storage time constants can be evaluated

G-APD
Quartz lightguide

\(\sim 4000\) mm

(L. Göttl / PSI)
The final assembly of PSI's UCN source is well underway

- D$_2$O system: commissioning completed
- Proton Beam Line: commissioning completed
- Target: commissioning completed
- Storage Volume & Neutron Guides: ready for installation
- ColdModerator System: assembly close to completion

We expect first UCN in summer 2010

The first experiment (nEDM) will start taking data in late 2010 with a strong international collaboration

Thank you!
2nd International Workshop on the Physics of fundamental Symmetries and Interactions at low energies and the precision frontier.

Topics:
- Low energy precision tests of the Standard Model
- Searches for symmetry violations – e.g. T, CP, CPT, Lorentz, Lepton flavor, Baryon number
- Searches for new forces – e.g. spin dependent interactions, modifications of gravity or weak interaction
- Precision measurements of fundamental constants
- Fundamental physics with cold and ultracold neutrons
- Advanced ultracold neutron sources
- Searches for permanent electric dipole moments
- Precision experiments with pions and muons
- Advanced muon sources
- Exotic atoms and molecules
- Precision magnetometry
- Advanced detector technologies

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